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Kobayashi et al.

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(54) **INK JET RECORDING APPARATUS**

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(52) **U.S. Cl.** **347/23**; 347/7
(58) **Field of Search** 347/23, 7, 14

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,663,750 * 9/1997 Sakuma 347/7
5,828,389 * 10/1998 Yamaguchi et. al. 347/23
5,844,583 * 12/1998 Onishi et al. 347/16
5,847,726 * 12/1998 Hori 347/23
5,880,751 * 3/1999 Nishikori et al. 347/14
6,000,778 * 12/1999 Koitabashi et al. 347/23

FOREIGN PATENT DOCUMENTS

0 398 348 11/1990 (EP) B41J/2/165
0 552 472 7/1993 (EP) B41J/2/165
615 846 * 9/1994 (EP) B41J/2/175
0 615 846 9/1994 (EP) B41J/2/175
0 707 969 * 4/1996 (EP) B41J/2/17
519467 3/1993 (JP) .
588552 4/1993 (JP) .
7205419 8/1995 (JP) .
82649 1/1996 (JP) .
WO 92/18335 * 10/1992 (WO) B41J/2/175

OTHER PUBLICATIONS

Patent Abstracts Of Japan vol. 096, No. 002, Feb. 29, 1996, & JP 07 276667 A (Brother Ind Ltd) Oct. 29, 1996 *Abstract.

Patent Abstracts Of Japan, vol. 096, No. 003, Mar. 29, 1996, & JP 07 309018 A (Brother Ind Ltd) Nov. 28, 1995 *Abstract.

* cited by examiner

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(57) **ABSTRACT**

An ink jet recording apparatus includes an ink consumption operating unit that adds a quantity of ink to be discharged by suction processing as a quantity of ink consumed before performing the suction processing. The ink jet recording apparatus includes also a suction control unit that performs the suction processing after such addition. A remaining ink level is calculated by estimating a quantity of ink to be used in a large volume for sucking as a quantity of ink consumed, and, even if a power supply switch is turned off before the sucking operation is terminated, the calculated remaining ink level as a quantity of ink consumed is added to a consumption storage unit **33**. As a result, a possible erroneous overestimation of the remaining ink level in an ink cartridge can be avoided.

36 Claims, 9 Drawing Sheets

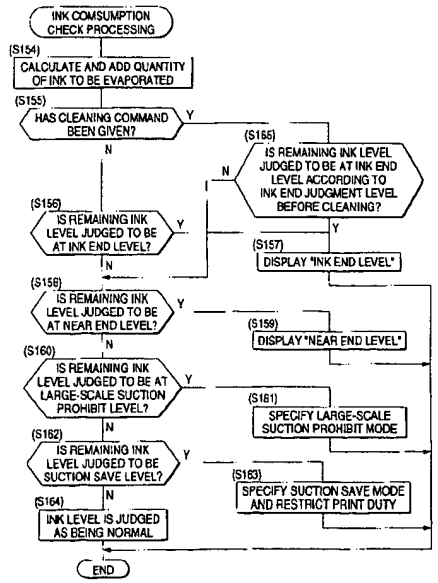


FIG. 1

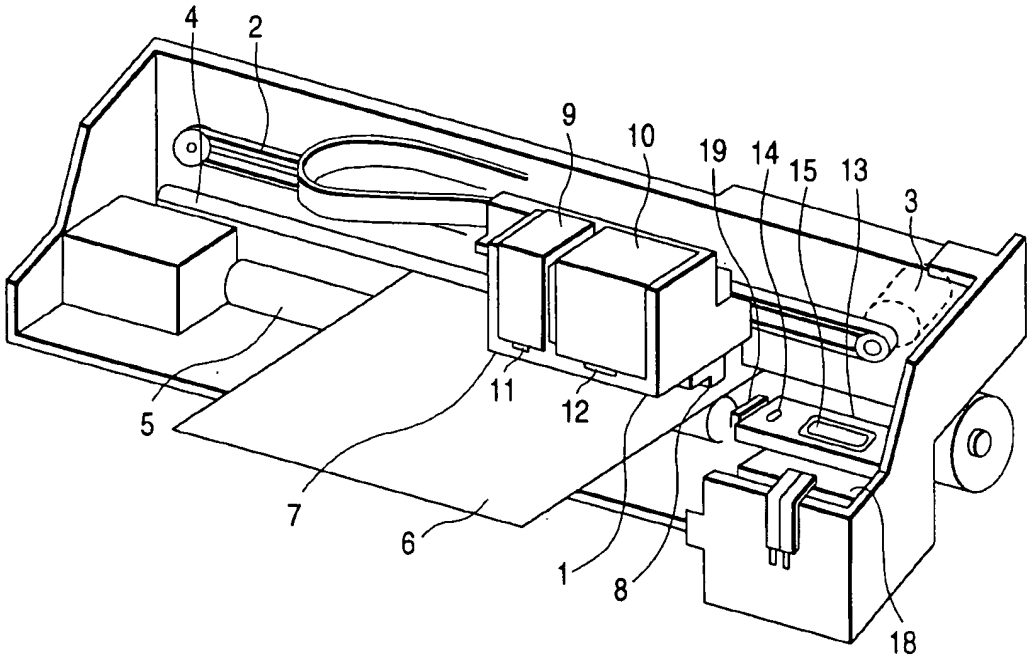


FIG. 2

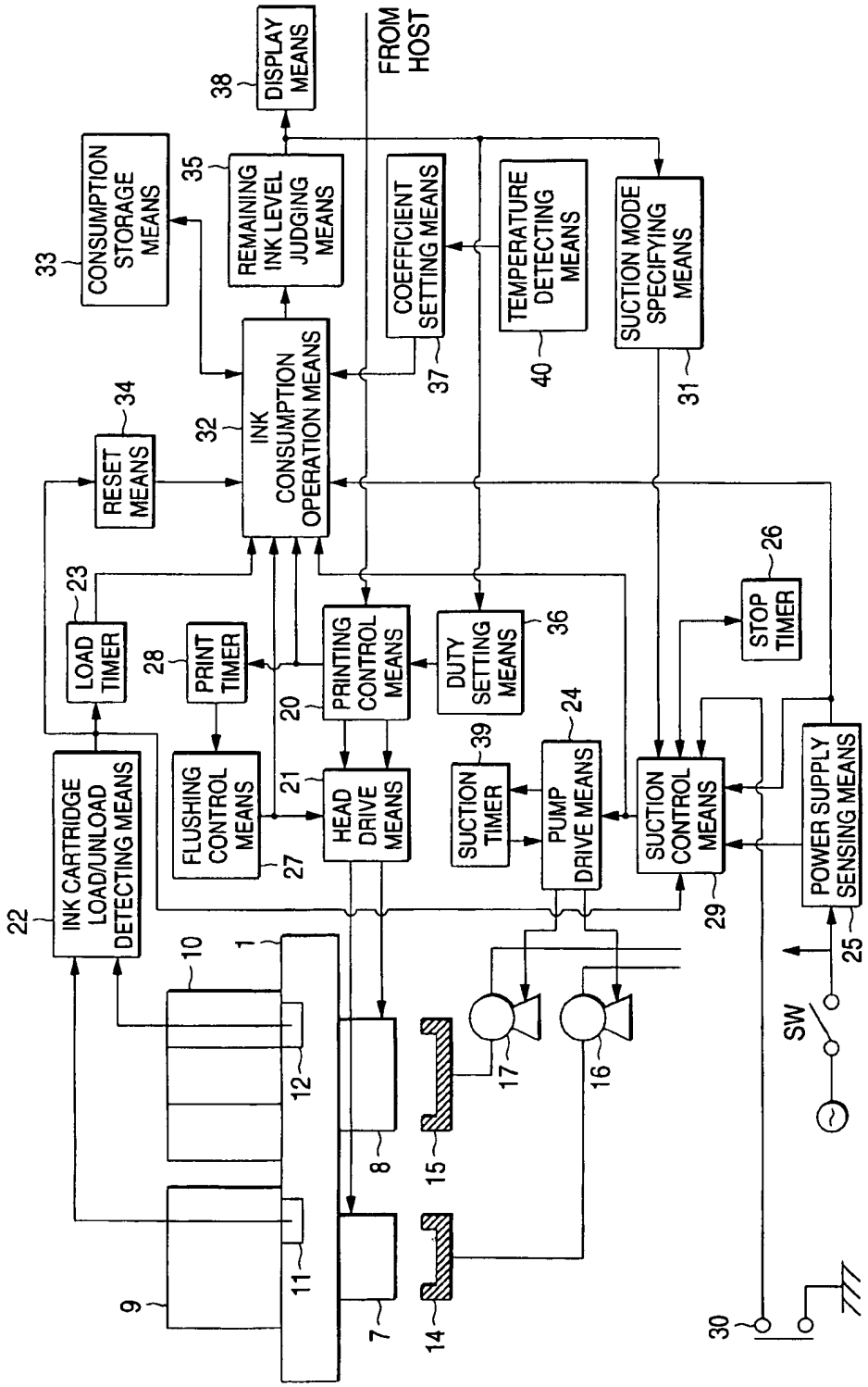

DISPLAY MEANS
38
FROM HOST
CONSUMPTION STORAGE MEANS
33
REMAINING INK LEVEL JUDGING MEANS
35
COEFFICIENT SETTING MEANS
37
TEMPERATURE DETECTING MEANS
40
SUCTION MODE SPECIFYING MEANS
31
INK CONSUMPTION OPERATION MEANS
32
RESET MEANS
34
LOAD TIMER
23
PRINT TIMER
28
PRINTING CONTROL MEANS
20
DUTY SETTING MEANS
36
STOP TIMER
26
INK CARTRIDGE LOAD/UNLOAD DETECTING MEANS
22
FLUSHING CONTROL MEANS
27
HEAD DRIVE MEANS
21
SUCTION TIMER
39
PUMP DRIVE MEANS
24
SUCTION CONTROL MEANS
29
POWER SUPPLY SENSING MEANS
25
SW
30
1
10
12
8
15
17
16
9
11
7
14

FIG. 3

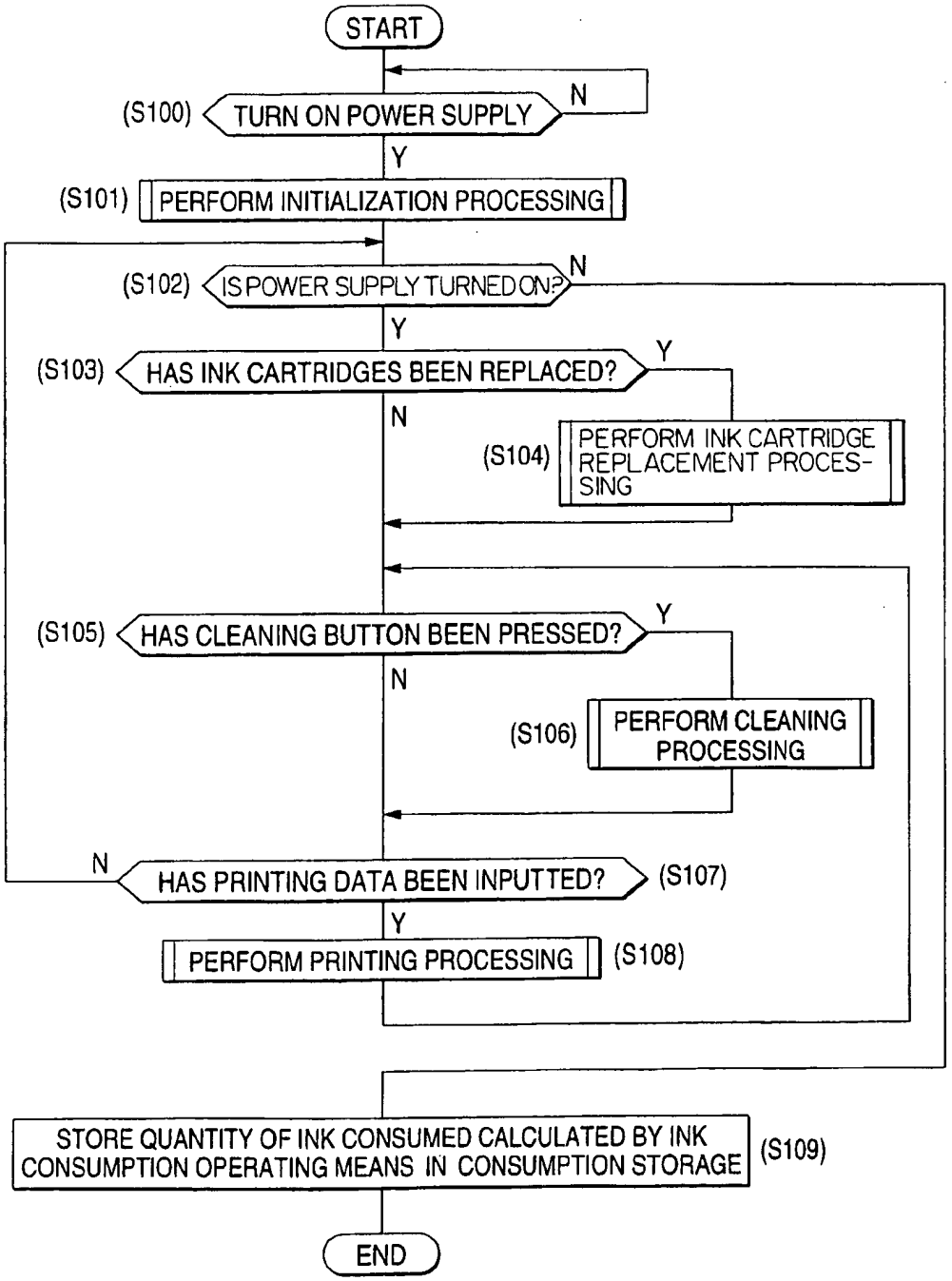

START
(S100)
TURN ON POWER SUPPLY
N
Y
(S101)
PERFORM INITIALIZATION PROCESSING
(S102)
IS POWER SUPPLY TURNED ON?
N
Y
(S103)
HAS INK CARTRIDGES BEEN REPLACED?
Y
N
(S104)
PERFORM INK CARTRIDGE REPLACEMENT PROCESSING
(S105)
HAS CLEANING BUTTON BEEN PRESSED?
Y
N
(S106)
PERFORM CLEANING PROCESSING
N
HAS PRINTING DATA BEEN INPUTTED?
(S107)
Y
PERFORM PRINTING PROCESSING
(S108)
STORE QUANTITY OF INK CONSUMED CALCULATED BY INK CONSUMPTION OPERATING MEANS IN CONSUMPTION STORAGE
(S109)
END

FIG. 4

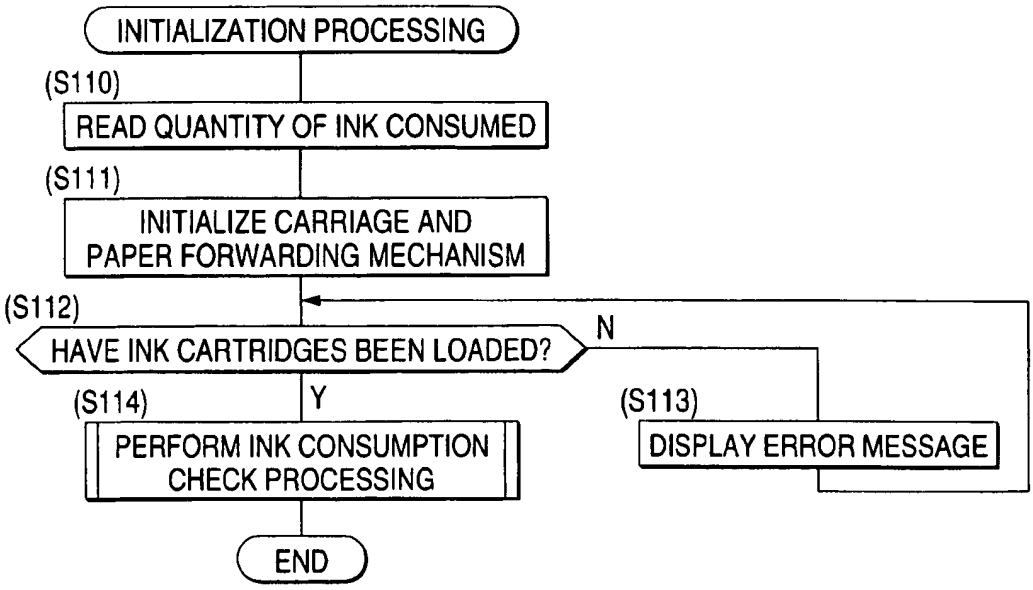

INITIALIZATION PROCESSING
(S110)
READ QUANTITY OF INK CONSUMED
(S111)
INITIALIZE CARRIAGE AND PAPER FORWARDING MECHANISM
(S112)
HAVE INK CARTRIDGES BEEN LOADED?
N
Y
(S114)
PERFORM INK CONSUMPTION CHECK PROCESSING
(S113)
DISPLAY ERROR MESSAGE
END

FIG. 5

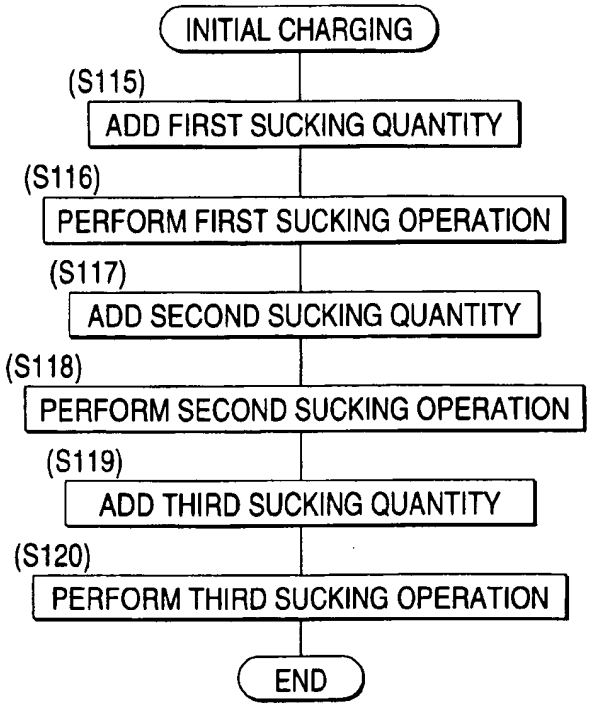

INITIAL CHARGING
(S115)
ADD FIRST SUCKING QUANTITY
(S116)
PERFORM FIRST SUCKING OPERATION
(S117)
ADD SECOND SUCKING QUANTITY
(S118)
PERFORM SECOND SUCKING OPERATION
(S119)
ADD THIRD SUCKING QUANTITY
(S120)
PERFORM THIRD SUCKING OPERATION
END

FIG. 6

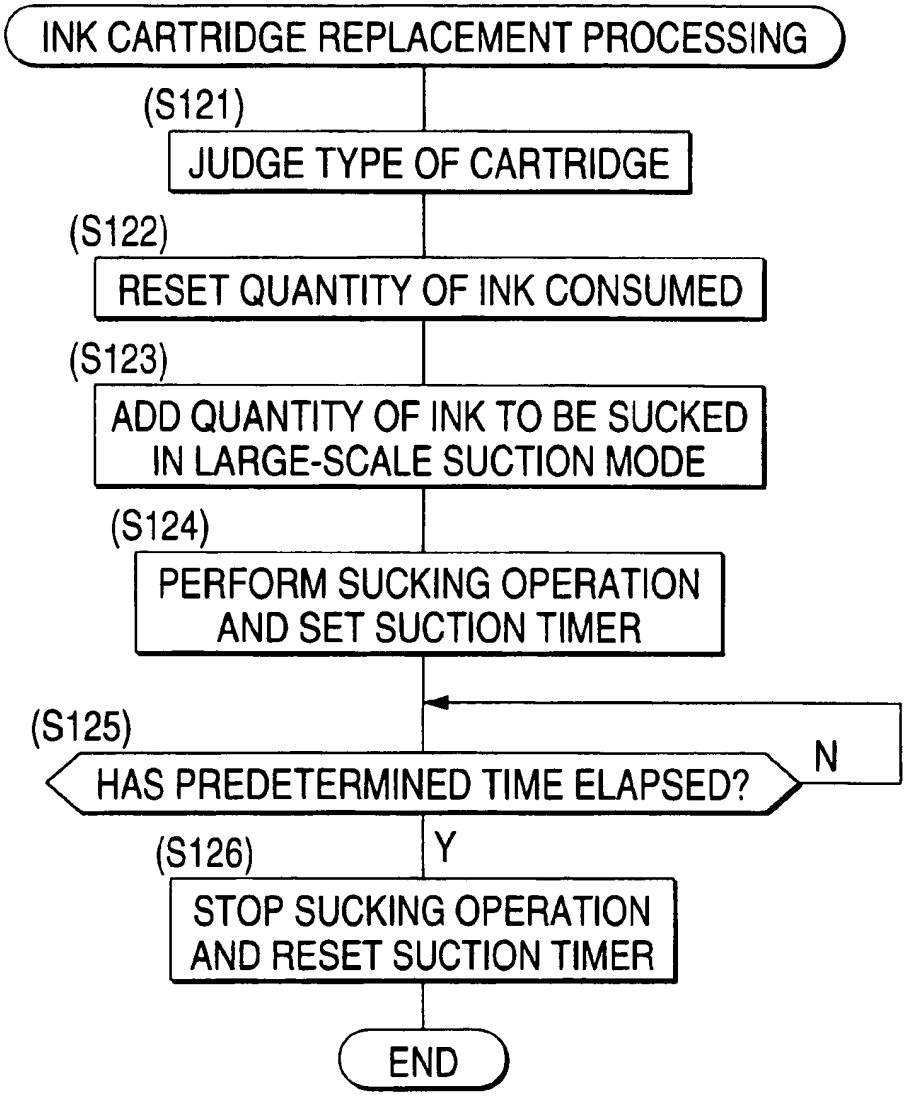

INK CARTRIDGE REPLACEMENT PROCESSING
(S121)
JUDGE TYPE OF CARTRIDGE
(S122)
RESET QUANTITY OF INK CONSUMED
(S123)
ADD QUANTITY OF INK TO BE SUCKED IN LARGE-SCALE SUCTION MODE
(S124)
PERFORM SUCKING OPERATION AND SET SUCTION TIMER
(S125)
HAS PREDETERMINED TIME ELAPSED?
N
Y
(S126)
STOP SUCKING OPERATION AND RESET SUCTION TIMER
END

FIG. 7

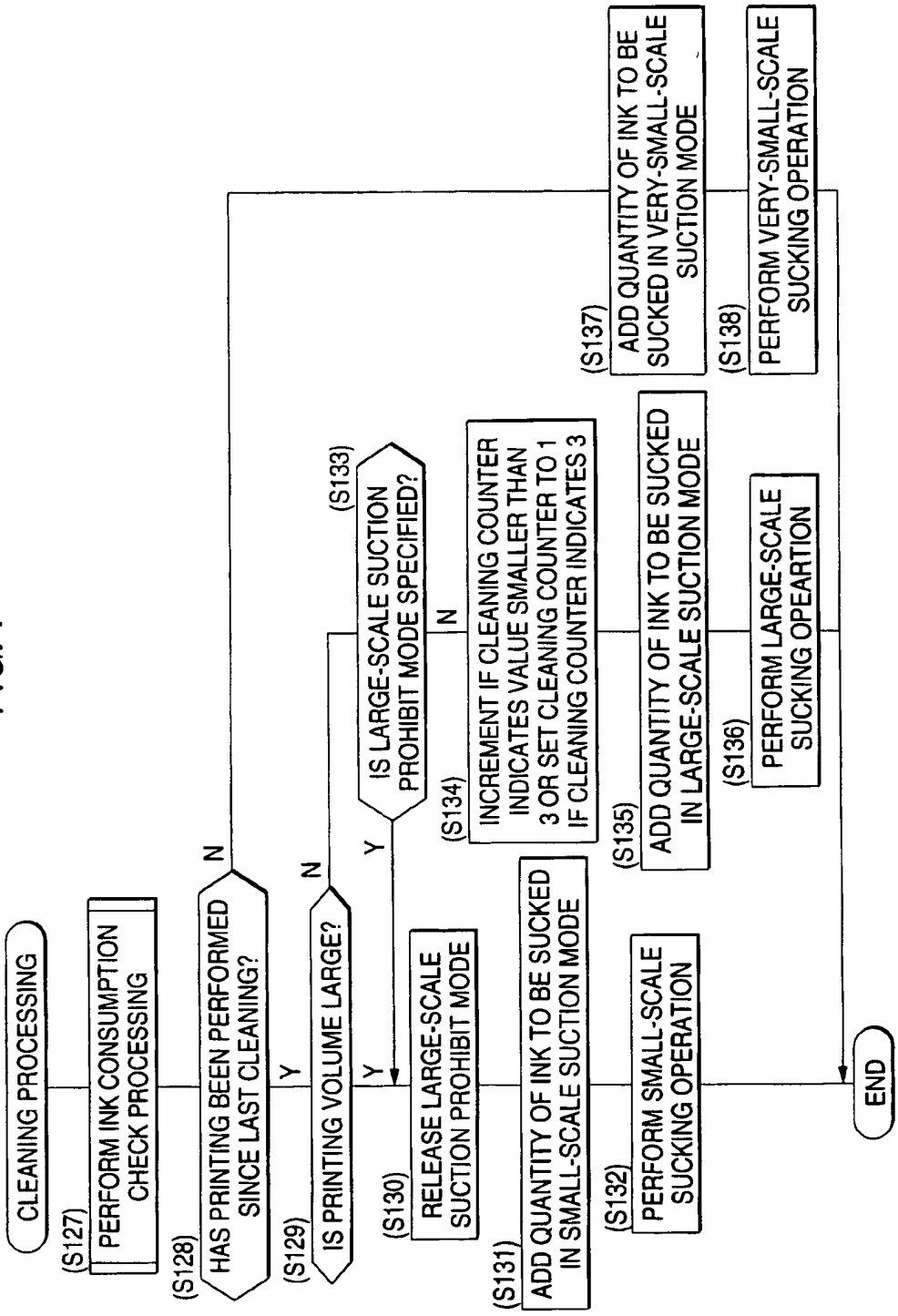

CLEANING PROCESSING
(S127)
PERFORM INK CONSUMPTION CHECK PROCESSING
(S128)
HAS PRINTING BEEN PERFORMED SINCE LAST CLEANING?
N
Y
(S129)
IS PRINTING VOLUME LARGE?
N
Y
(S133)
IS LARGE-SCALE SUCTION PROHIBIT MODE SPECIFIED?
Y
N
(S130)
RELEASE LARGE-SCALE SUCTION PROHIBIT MODE
(S134)
INCREMENT IF CLEANING COUNTER INDICATES VALUE SMALLER THAN 3 OR SET CLEANING COUNTER TO 1 IF CLEANING COUNTER INDICATES 3
(S131)
ADD QUANTITY OF INK TO BE SUCKED IN SMALL-SCALE SUCTION MODE
(S135)
ADD QUANTITY OF INK TO BE SUCKED IN LARGE-SCALE SUCTION MODE
(S137)
ADD QUANTITY OF INK TO BE SUCKED IN VERY-SMALL-SCALE SUCTION MODE
(S132)
PERFORM SMALL-SCALE SUCKING OPERATION
(S136)
PERFORM LARGE-SCALE SUCKING OPEARTION
(S138)
PERFORM VERY-SMALL-SCALE SUCKING OPERATION
END

FIG. 8

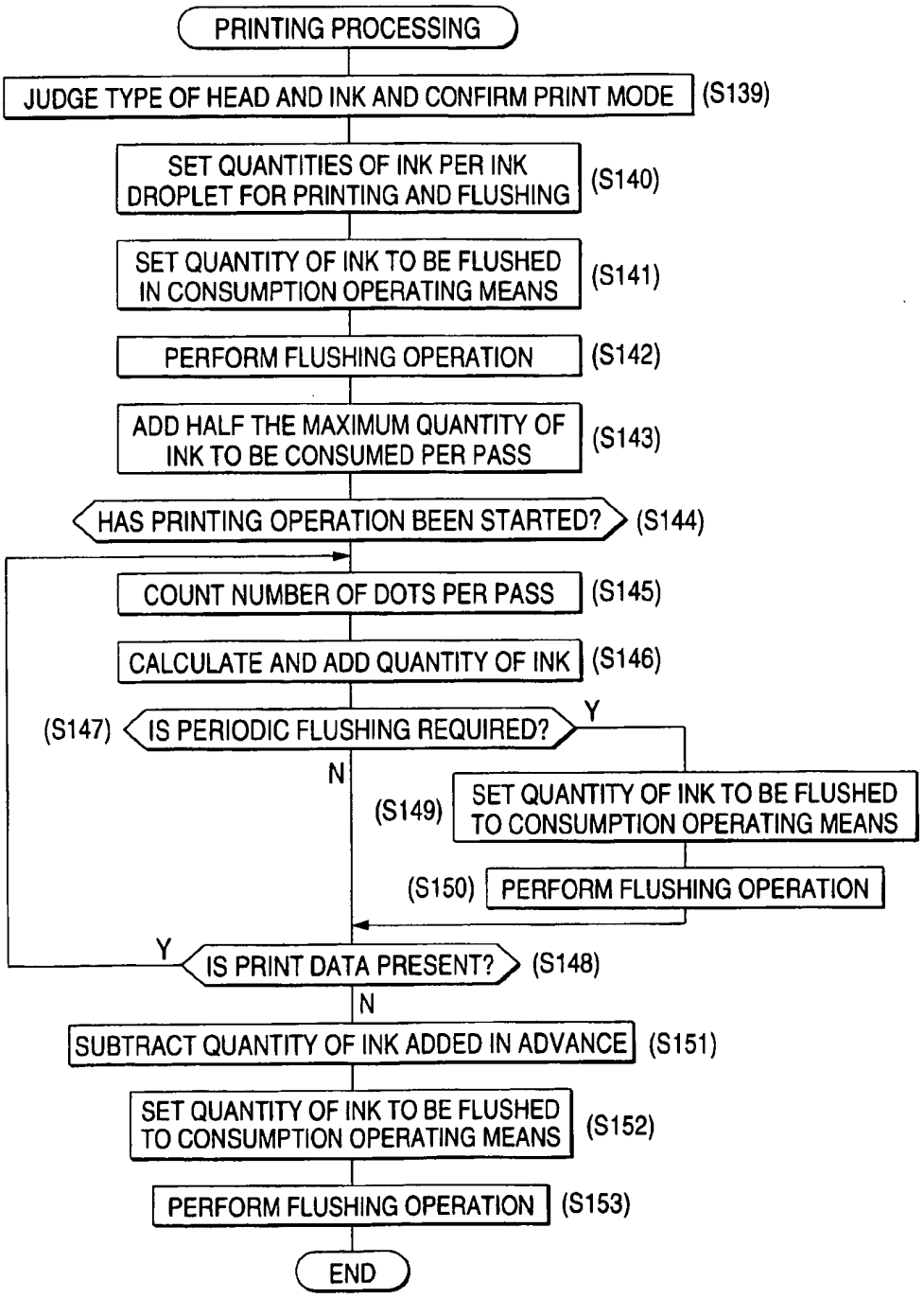

PRINTING PROCESSING
JUDGE TYPE OF HEAD AND INK AND CONFIRM PRINT MODE
(S139)
SET QUANTITIES OF INK PER INK DROPLET FOR PRINTING AND FLUSHING
(S140)
SET QUANTITY OF INK TO BE FLUSHED IN CONSUMPTION OPERATING MEANS
(S141)
PERFORM FLUSHING OPERATION
(S142)
ADD HALF THE MAXIMUM QUANTITY OF INK TO BE CONSUMED PER PASS
(S143)
HAS PRINTING OPERATION BEEN STARTED?
(S144)
COUNT NUMBER OF DOTS PER PASS
(S145)
CALCULATE AND ADD QUANTITY OF INK
(S146)
(S147)
IS PERIODIC FLUSHING REQUIRED?
Y
N
(S149)
SET QUANTITY OF INK TO BE FLUSHED TO CONSUMPTION OPERATING MEANS
(S150)
PERFORM FLUSHING OPERATION
Y
IS PRINT DATA PRESENT?
(S148)
N
SUBTRACT QUANTITY OF INK ADDED IN ADVANCE
(S151)
SET QUANTITY OF INK TO BE FLUSHED TO CONSUMPTION OPERATING MEANS
(S152)
PERFORM FLUSHING OPERATION
(S153)
END

FIG. 9

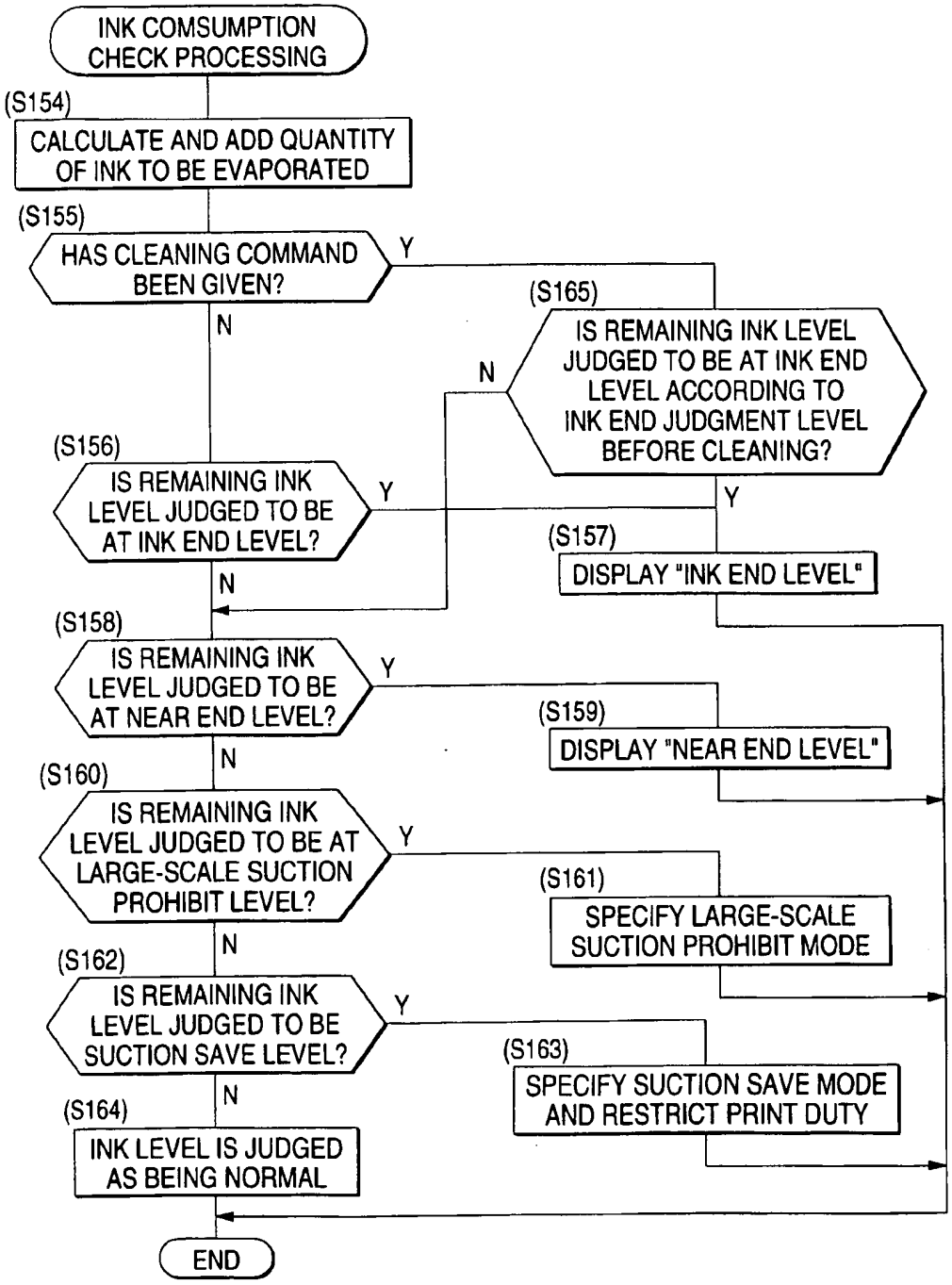

INK COMSUMPTION CHECK PROCESSING
(S154)
CALCULATE AND ADD QUANTITY OF INK TO BE EVAPORATED
(S155)
HAS CLEANING COMMAND BEEN GIVEN?
Y
N
(S165)
IS REMAINING INK LEVEL JUDGED TO BE AT INK END LEVEL ACCORDING TO INK END JUDGMENT LEVEL BEFORE CLEANING?
N
Y
(S156)
IS REMAINING INK LEVEL JUDGED TO BE AT INK END LEVEL?
Y
N
(S157)
DISPLAY "INK END LEVEL"
(S158)
IS REMAINING INK LEVEL JUDGED TO BE AT NEAR END LEVEL?
Y
N
(S159)
DISPLAY "NEAR END LEVEL"
(S160)
IS REMAINING INK LEVEL JUDGED TO BE AT LARGE-SCALE SUCTION PROHIBIT LEVEL?
Y
N
(S161)
SPECIFY LARGE-SCALE SUCTION PROHIBIT MODE
(S162)
IS REMAINING INK LEVEL JUDGED TO BE SUCTION SAVE LEVEL?
Y
N
(S163)
SPECIFY SUCTION SAVE MODE AND RESTRICT PRINT DUTY
(S164)
INK LEVEL IS JUDGED AS BEING NORMAL
END

FIG. 10

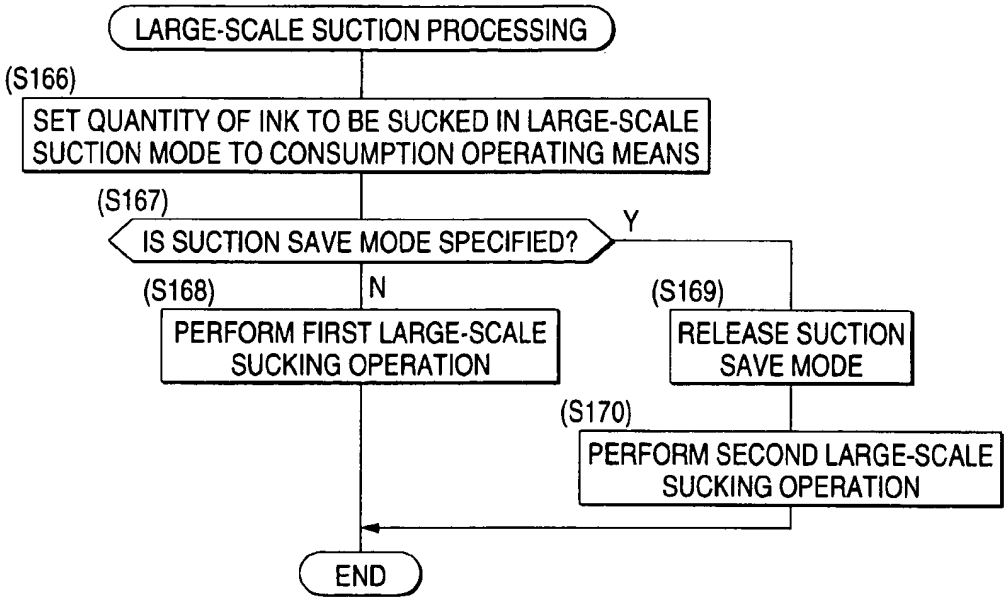
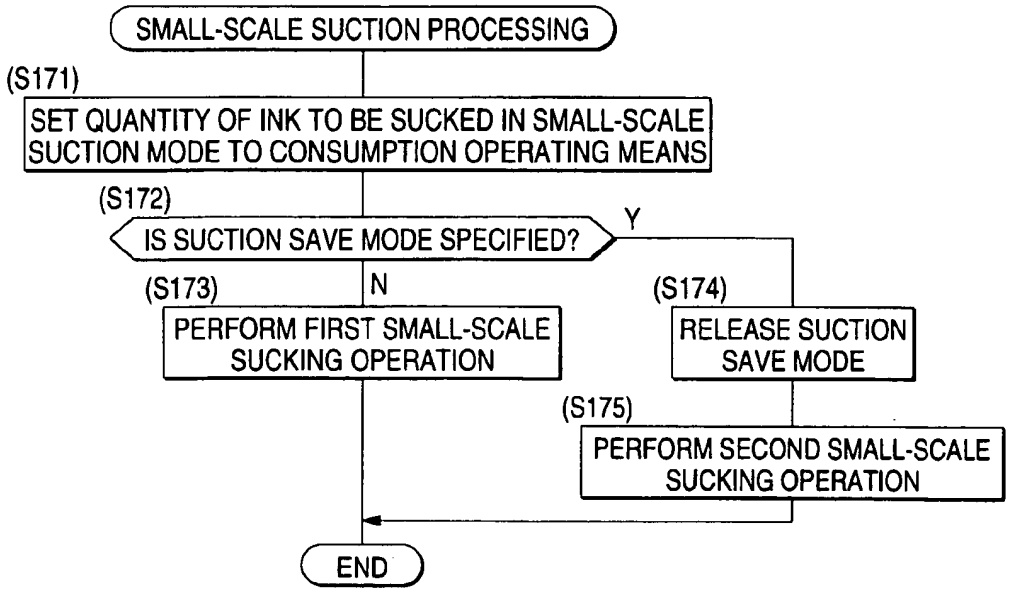

LARGE-SCALE SUCTION PROCESSING
(S166)
SET QUANTITY OF INK TO BE SUCKED IN LARGE-SCALE SUCTION MODE TO CONSUMPTION OPERATING MEANS
(S167)
IS SUCTION SAVE MODE SPECIFIED?
Y
N
(S168)
PERFORM FIRST LARGE-SCALE SUCKING OPERATION
(S169)
RELEASE SUCTION SAVE MODE
(S170)
PERFORM SECOND LARGE-SCALE SUCKING OPERATION
END

FIG. 11


SMALL-SCALE SUCTION PROCESSING
(S171)
SET QUANTITY OF INK TO BE SUCKED IN SMALL-SCALE SUCTION MODE TO CONSUMPTION OPERATING MEANS
(S172)
IS SUCTION SAVE MODE SPECIFIED?
Y
N
(S173)
PERFORM FIRST SMALL-SCALE SUCKING OPERATION
(S174)
RELEASE SUCTION SAVE MODE
(S175)
PERFORM SECOND SMALL-SCALE SUCKING OPERATION
END

INK JET RECORDING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the invention

The invention relates to an ink jet recording apparatus that has a recording head that moves across the width of a recording paper and forms images by jetting ink droplets onto the recording paper so as to coincide with printing data. More specifically, the invention is directed to a technique for controlling the quantity of ink in an ink cartridge.

2. Related Art

An ink jet printer is an apparatus (i.e., an ink jet recording apparatus) that includes an ink jet recording head. The ink jet recording head is supplied with ink from a source of ink such as an ink cartridge (i.e., a means for storing ink, which may be referred to as ink storage means for convenience). The ink jet printer also includes means for moving the recording paper relative to the recording head (for convenience, this may be referred to as paper forwarding means. The ink jet printer makes a recording by jetting ink droplets from the recording head in correspondence with a print signal.

Because the ink used is a liquid, an ink jet printer must perform a variety of secondary operations and certain types of processing that are not required in printers having wire dot recording heads or thermal recording heads. In particular, some of the operations required of an ink jet recording apparatus are the charging of ink into the recording head, the forcible sucking and discharging of the ink from the recording head to prevent clogging (due to the volatilization of an ink solvent), and the control over the remaining ink level in the ink storage means.

Particular attention will now be paid to this latter operation, that is, the control over the remaining ink level in an ink storage means such as an ink cartridge.

One approach to controlling over the remaining ink level is a hardware-based detection technique. According to this first approach, liquid level detecting means (such as electrodes) are attached to the ink storage means. This approach has drawbacks. In particular, providing liquid level detection hardware requires a more complicated structure for the ink storage means. This more complicated structure increases the cost of manufacture.

Another approach to controlling the remaining ink level is a software-based approach. This second approach helps to overcome the drawbacks of the first approach. Examples of this second, software-based approach may be found in (1) Examined Japanese Patent Publication No. Hei. 5-19467, (2) Examined Japanese Patent Publication No. Hei. 8-2649, (3) Unexamined Japanese Patent Publication No. Hei. 5-88552, and (4) Unexamined Japanese Patent Publication No. Hei. 7-205419. The foregoing four examples of the second approach mention software which involves steps like:

- integrating quantities of ink consumed, using a counter, based on the sum of the product of the number of dots during printing and the quantity of ink to be consumed per ink droplet and the product of the quantity of ink to be sucked per forced sucking operation for preventing the clogging of nozzle openings and the number of sucking operations;
- displaying the remaining ink level by storing the integrated quantity of ink consumed; and
- allowing the integrated quantity of ink consumed to be reset through an external operation. That is, the approach to the control of the remaining ink level evidenced in the four examples mentioned above is to use software. As the example steps just shown reveal, the general software-based approach takes advantage of the functions of a microcomputer incorporated in the recording apparatus.

An ink jet recording apparatus that controls the remaining ink level by means of software, as in the above-identified second approach, can consecutively compute the quantity of ink consumed in relative terms correctly, although ink end detection accuracy may not be so satisfactory. Therefore, by displaying the thus-computed quantity of ink consumed, the user can be kept informed of how much ink is being consumed. Color ink jet printers now are commonly in practical use. Color ink jet printers use diversified techniques to achieve high printing quality. Some of these diversified techniques include using dark and light inks, adjusting the quantity of ink per ink droplet based on printing data, and changing print resolution in accordance with images and texts. All of these techniques tend to complicate proper control under the second approach described above.

Another complicating factor relates to the maintenance processing of the printer. Maintenance processing includes the actions taken to prevent the clogging of the ink jet recording head. During such maintenance processing, certain quantities of ink are forcibly jetted or flushed from the ink jet recording head. Of course, this ink comes from the ink storage means and must be accounted for. The quantities of ink to be forcibly jetted and flushed are meticulously specified, in a variety of ways, and the actual quantity consumed may vary in accordance with the present or recent operations of the recording head.

The diversified techniques of color ink jet printing and the maintenance processing for preventing clogs result in a very complicated situation for which ink consumption must be predicted under the second (software-based) approach. The above-identified four examples of the second approach for controlling the remaining ink level cannot take care of such a complicated ink consumption situation without producing grave errors. The above-identified software-based approaches do not meet the requirement for providing an accurate determination of the remaining ink level. Because the remaining ink level cannot correctly be computed under the above-identified software-based approaches, there is an increased risk of damage to ink jet recording heads operating under such approaches. In particular, the printer might attempt to jet ink droplets from the ink jet recording head even after all of the ink is used up. Such an operation might easily cause fatal damage to an ink jet recording head due to the ink sucking operations performed for maintenance.

There is yet another drawback to the above-identified four examples of the second approach to control of the remaining ink level. This drawback relates to the already mentioned counter. In particular, there may be a requirement that the user reset the remaining ink level control counter by operating a reset button whenever replacing an ink cartridge. If the user replaces the cartridge without resetting the counter, an inconvenient situation arises. That is, because the user has forgotten to operate the reset button, printing operations cannot be performed even though the ink storage means (i.e., the ink cartridge) has available a plentiful supply of ink.

SUMMARY OF THE INVENTION

The invention seeks to overcome the shortcomings and drawbacks mentioned above.

The invention is applied to an ink jet recording apparatus that includes: an ink jet recording head for jetting an ink droplet so as to correspond to printing data; an ink cartridge

for supplying ink to the recording head; a capping means not only sealing the recording head but also being subjected to a negative pressure by a suction pump; a suction control means for controlling suction processing for discharging the ink by sucking the recording head with the suction pump; and a remaining ink level judging means for controlling a quantity of ink in the ink cartridge by integrating quantities of ink discharged from the recording head. In such ink jet recording apparatus, the remaining ink level judging means adds a quantity of ink to be discharged by the suction processing as a quantity of ink consumed, the addition being made before performing the suction processing, and the suction processing is thereafter performed.

The remaining ink level is calculated by estimating the quantity of ink to be used in a large volume for sucking as the quantity of ink consumed. Therefore, even if a power supply switch is turned off before the sucking operation is brought to an end, a possible erroneous overestimation of the remaining ink level in an ink cartridge can be precluded. Hence, the recording head can be prevented from being damaged by the sucking of ink and the printing performed with the remaining ink level being low.

Therefore, a first object of the invention is to provide an ink jet recording apparatus that can prevent the recording head from being damaged accidentally even if the ink has been consumed in large quantities due to sucking operations and the like by computing the quantity of ink in the ink cartridge while minimizing erroneous integration of such quantity to be caused by the turning off of the power supply or the like.

A second object of the invention is to provide an ink jet recording apparatus that can prevent the recording head from being broken by adjusting the quantity of ink to be sucked for the maintenance of the recording head based on the correctly computed quantity of ink consumed.

A third object of the invention is to provide an ink jet recording apparatus that can print data with the highest possible quality even if the ink remaining in the ink cartridge is at a near end level.

A fourth object of the invention is to provide an ink jet recording apparatus that can not only prevent the running out of ink by precluding underestimation of the quantity of ink to be sucked in association with the loading of an ink cartridge but also give a message to the effect that ink charging processing after loading the ink cartridge has been terminated.

A fifth object of the invention is to provide an ink jet recording apparatus that can judge the remaining ink level for a new ink cartridge by automatically resetting the quantity of ink consumed in the case where an old ink cartridge has been replaced with the remaining ink level therein being extremely low.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing an ink jet recording apparatus, which is an embodiment of the invention.

FIG. **2** is a block diagram showing an embodiment of the invention.

FIG. **3** is a flowchart showing the overall operation of the apparatus.

FIG. **4** is a flowchart showing an operation for initialization processing out of the operation of the apparatus.

FIG. **5** is a flowchart showing an operation for initial charging processing.

FIG. **6** is a flowchart showing an operation for ink cartridge replacement processing.

FIG. **7** is a flowchart showing an operation for cleaning processing.

FIG. **8** is a flowchart showing an operation for printing processing.

FIG. **9** is a flowchart showing an operation for ink consumption check processing out of the operation of the apparatus.

FIG. **10** is a flowchart showing large-scale suction processing, which is another embodiment of the invention.

FIG. **11** is a flowchart showing small-scale suction processing, which is another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows an embodiment of the invention. A carriage **1** is connected to a motor **3** through a timing belt **2** and moves in parallel to a platen **5** while guided by a guide member **4**. Recording heads **7, 8** are mounted on the carriage **1** surface that confronts a recording paper **6**. The recording head **7** jets black ink onto a printing region (left side as viewed in FIG. **1**) and the color printing recording head **8** is releasably mounted in a nonprinting region. The respective recording heads **7, 8** jet ink droplets onto the recording paper **6** while having inks supplied by a black ink cartridge **9** and a color ink cartridge **10**, respectively. Further, switches **11, 12** are disposed on the carriage **1**. These switches **11, 12** are turned on and off upon loading and unloading the ink cartridges **9, 10**.

A capping device **13** is formed by mounting a cap member **14** for sealing the black ink recording head **7** and a cap member **15** for sealing the color ink recording head **8** on the same slider. The cap members **14, 15** are large enough to seal the nozzle opening surfaces of the recording heads **7, 8** in single spaces, respectively, and are connected through tubes to a pump unit **18**. The capping device **13** thus is an example of means for sealing the ink jet recording head.

The pump unit **18** includes two pumps **16, 17** that can be driven independently. As a result of this construction, the capping device **13** seals the nozzle openings during a nonprinting period, and forcibly discharges ink from the recording heads **7, 8** while being subjected to a negative pressure by the pump unit **18** when the ink jetting capability recovering operation is being performed. Further, a cleaner unit **19** is disposed in the vicinity of the capping device **13**. Thus, the capping device **13** is an example of a structure that also doubles as a means for allowing the ink jet recording head to be subjected to a negative pressure by the suction pump. Although the capping device performs the above-identified functions for sealing and for suction, it may, for convenience, be referred to simply as a capping means.

FIG. **2** shows a controller for controlling the operation of the recording apparatus, the controller being an embodiment of the invention. A printing control means **20** generates bit map data based on printing data sent from a host, and jets ink droplets out of the recording heads **7, 8** by causing a head drive means **21** to produce drive signals based on the generated bit map data.

An ink cartridge load/unload detecting means **22** detects the loading and unloading of the ink cartridges **9, 10** from signal changeovers of the respective switches **11, 12** disposed on the carriage **1**. A load timer **23** resets itself upon loading the ink cartridges **9, 10** based on a signal from the ink cartridge load/unload detecting means **22** and thereafter starts measuring time, and then stops measuring time upon unloading the ink cartridges **9, 10**.

A pump driving means **24** performs a sucking operation based on the sucking strength, the sucking time, and the sucking interval defined by a suction control means **29** to be described later. A power supply sensing means **25** detects the supply of power to the apparatus, and outputs a signal upon the turning on and off the power supply. A stop timer **26** starts measuring time upon turning off the power supply and stops measuring time upon turning on the power supply. That is, the stop timer **26** detects a time period during which the recording heads **7, 8** have continuously been sealed by the capping device **13**.

A flushing control means **27** jets a predetermined number of ink droplets out of all the nozzle openings of the respective recording heads **7, 8** after the carriage **1** has been evacuated to a flushing position, usually at the capping position, by the printing control means **20** upon detection by a print timer **28** of a predetermined time period for which a printing operation has lasted. The flushing operation is performed to prevent and eliminate nozzle clogging.

The suction control means **29** operates the respective pumps **17, 18** in a predetermined mode by delivering a signal to the pump drive means **24** with the recording heads **7, 8** sealed by the capping device **13** based on a signal from a suction mode specifying means **31** to be described later. The suction control means **29** is designed to intervene when a signal is received from an externally operable cleaning switch **30**, when new ink cartridges **9, 10** are loaded, or when the stop timer **26** has measured a predetermined time upon turning on the power supply. The suction mode specifying means **31** specifies a mode selected from one of three possible modes: large-scale suction mode, a small-scale suction mode, and a suction save mode in accordance with the remaining ink level of the ink cartridges **9, 10**.

An ink consumption operating means **32** reads the value corresponding to the quantity of ink consumed, which value is stored in a consumption storage means **33** to be described later. The ink consumption operating means **32** performs this reading operation when power supply sensing means **25** senses the turning on of the power supply.

The ink consumption operating means counts the number of ink droplets whenever a printing operation or a flushing operation is performed. Based on the counted number of ink droplets, the ink consumption operating means calculates the quantity of ink consumed. This calculation of the quantity of ink consumed may be performed by multiplying the counted number of ink droplets by the quantity of ink per ink droplet. The quantity of ink used per ink droplet may be based on data stored in a coefficient setting means **37** to be described later.

When the suction control means **29** gives a suction command to the pump drive means **24**, the ink consumption operating means may perform the calculation of the quantity of ink consumed by adding the quantity of ink to be sucked in advance.

The coefficient setting means **37** stores data relating to the quantity of ink per ink droplet for color and black inks as shown in Tables 1 and 2. That is, the coefficient setting means **37** stores data on the quantity by weight of ink per ink droplet for color and black inks so as to correspond to print modes such as a high-definition print mode, a normal print mode, and a draft print mode as shown in Table 1. Further, the coefficient setting means **37** stores data on the quantity by weight of ink per ink droplet for color and black inks so as to correspond not only to flushing operations (such as flushing before printing, periodic flushing during printing, and flushing after printing) but also to print modes for periodic flushing.

It is preferred that the quantity of ink per ink droplet be calculated so as to be temperature-compensated based on temperature data sent from a temperature detecting means **40**. To explain, it is assumed that at room temperature the ink droplet has a reference value of 1. At a temperature of 30° C., the quantity of ink per ink droplet is actually about 1.03 times that of the reference value. At a temperature of 40° C., the quantity of ink per ink droplet is actually about 1.05 times that of the reference value. As operating temperatures rise above room temperature, the quantity of the ink discharged has a larger volume due to the reduced viscosity caused by increased temperature. Thereby, the amount of ink expended per ink droplet can reliably be added as a quantity of ink consumed. Therefore, this temperature compensation contributes greatly to determining correctly the ink consumption and thus is particularly contributory to preventing the running out of the ink during printing.

When the power supply sensing means **25** detects the turning off of the power supply, the calculated quantity of ink consumed is stored in the consumption storage means **33**, and when a signal from a reset means **34** is applied upon detection of replacement of the ink cartridges **9, 10** by the ink cartridge load/unload detecting means **22**, the calculated values are reset.

A remaining ink level judging means **35** calculates a difference between the quantity of ink contained in the respective ink cartridges **9, 10** and the quantity of ink consumed as calculated by the ink consumption operating means **32**, and feeds a signal to the suction mode specifying means **31**, and to a duty setting means **36** and a display means **38**, which will be described later, every time the difference falls below one of a plurality of reference values that are defined by graduation.

That is, as shown in Table 3, the following remaining ink levels are available: two ink end levels, a near end level, a large-scale suction prohibit level, and a suction prohibit level. The ink end levels include a level in which the ink within the ink cartridges has run out and a level in which ink at least some remains in the ink cartridges after an ink sucking operation has been performed. The near end level is a level in which some 2 to 20% of the total ink remains. The large-scale suction prohibit level is a level in which some 2 to 25% of the total ink remains. The suction prohibit level is a level in which some 2 to 30% of the total ink remains.

Out of the aforementioned parts and components, it is preferred that the ink consumption operating means **32**, of which a particularly high calculation capability is required, be incorporated as part of the function of the CPU belonging to the host apparatus through the printer driver software installed into the host apparatus.

The operation of the thus constructed apparatus will now be described based on the flowcharts shown in FIGS. **3** through **9**.

Overall Operation

See FIG. **3**. Upon turning a power supply switch SW on (**S100**), initialization processing (FIG. **4**), which will be described later, is performed (**S101**). Then it is judged whether or not the power supply remains on (**S102**). If the power supply switch is off when this step is performed, the overall operation is brought to an end after the power supply turn-off processing has been performed (**S109**). The power supply turn-off processing includes storing the quantity of ink calculated by the consumption operating means **32** into the consumption storage means **33**.

On the other hand, if the power supply is on when step **S102** is performed, a determination is made as to whether or

not the ink cartridges **9, 10** have been replaced (**S103**). This determination is based on a signal from the ink cartridge load/unload detecting means **22**. If the ink cartridges have been replaced, ink cartridge replacement processing (FIG. **6**), which will be described later, is performed (**S104**).

Processing then continues with a determination as to whether the cleaning button or switch **30** has been pressed. If the ink cartridge replacement processing has not been performed or if the cleaning switch **30** has been pressed after replacement of the ink cartridges **9, 10** has been complete (**S105**), then cleaning processing (FIG. **7**), which will be described later, is performed (**S106**).

Processing thereafter continues with a determination as to whether there is any printing data (**S107**). If there presently is no printing data, the processing steps (**S102**) through (**S107**) are repeated. Thus, the printer waits for either the presence of printing data (detected at **S107**) or the shutting off of the power supply (detected at **S102**).

Upon reception of printing data, printing processing (FIG. **8**), which will be described later, is initiated (**S108**).

When the power supply switch SW is turned off, the operation is brought to an end after the quantity of ink consumed calculated by the ink consumption operating means **32** has been stored in the consumption storage means **33** (**S109**) and the stop timer **26** has been operated, if necessary.

Initialization Processing

See FIG. **4**. FIG. **4** shows the details of initialization processing according to an embodiment of the invention (refer to S101 of FIG. **3**). When the power supply sensing means **25** detects the turning on of the power supply, the consumption operating means **32** reads from the consumption storage means **33** the data relating to the quantity of ink already consumed (**S110**). The consumption storage means then performs initialization processing such as positioning carriage **1** and forwarding paper. These activities make the apparatus ready for printing (**S111**).

When the apparatus is ready for printing, processing continues with **S112** where a determination is made as to whether or not the ink cartridges **9, 10** are loaded. This determination is based on a signal from the ink cartridge load/unload detecting means **22**. If ink cartridges are not loaded, the display means **38** displays an error message (**S113**), and the apparatus stands by until the ink cartridges **9, 10** are loaded. Upon confirmation that the ink cartridges **9, 10** having been loaded correctly, ink consumption check processing, which will be described later, is performed (**S114**).

Ink Cartridge Initial Charging

See FIG. **5**. The ink jet recording apparatus is designed to jet ink droplets out of nozzle openings by causing pressure producing chambers to apply pressure to the ink. Therefore, in view of such design, the ink jet recording apparatus is required to maintain the same condition both during shipment and during operation. That is, for meeting such a requirement, measures to prevent the drying of the recording heads or entrance of dust into the recording heads are taken by charging a dummy solution into the recording heads. Therefore, prior to starting up the operation of the recording apparatus, the dummy solution charged into the recording heads **7, 8** must be completely discharged; i.e., a so-called initial loading operation must be performed.

In order reliably to account for the discharge of the dummy solution, a first quantity of ink to be sucked, which is the quantity of ink to be discharged by a first sucking operation, is added to the consumption operating means **32** in advance (**S115**). Next, a sucking operation is performed at the sucking speed specified for the first sucking operation (**S116**). Then, a second quantity of ink to be sucked, which is the quantity of ink to be discharged by a second sucking operation, is added to the consumption operating means **32** in advance (**S117**). Then, a sucking operation is performed at the sucking speed specified for the second sucking operation (**S118**). A third quantity of ink to be sucked, which is the quantity of ink to be discharged by a third sucking operation, is added to the consumption operating means **32** in advance (**S119**). Then, a sucking operation is performed at the sucking speed specified for the third sucking operation (**S120**).

Thus, the quantities of ink to be used for initial charging are added, in advance, on a step-by-step basis before sucking operations are performed with respect to the ink cartridges **9, 10** in large quantities. Therefore, even if the power supply is turned off during a sucking operation, the quantity of ink remaining in the ink cartridges **9, 10** can conservatively be estimated. As a result, the running out of ink during printing and the draining of ink out of the recording heads **7, 8** can be avoided.

Ink Cartridge Replacement Processing

See FIG. **6**. When the near end level or the ink end level is detected by the remaining ink level judging means **35** despite the fact that the ink cartridge load/unload detecting means **22** has detected the loading of new ink cartridges, the reset means **34** determines whether it is the black ink cartridge **9** or the color ink cartridge **10** that signals the detected ink level (**S121**). If it is the black ink cartridge **9** that signals the detected ink level, the quantity of ink consumed in the black ink cartridge is reset (**S122**), whereas if it is the color ink cartridge **10** that signals the detected ink level, the quantity of ink consumed in the color ink cartridge is similarly reset (**S122**).

As a result of this operation, the quantity of ink consumed can be automatically reset only by performing the ink cartridge replacement processing. That is, the ink consumption resetting operation to be performed by the user after the ink cartridges have been replaced can be dispensed with, and the resetting errors so often associated with the user can be precluded.

On the other hand, if the remaining ink level judging means **35** indicates other levels that are larger than the near end level, the ink consumption resetting operation is not performed by the ink consumption operating means **32** under the judgment that the user has erroneously unloaded and then loaded the same ink cartridges. In this case, even if it has been judged erroneously that the old ink cartridges have been unloaded and then loaded despite the fact that such old ink cartridges have actually been replaced with new ink cartridges, and even if the ink is thereafter sucked in large quantities for the cleaning processing and the like, the draining of ink from the recording heads **7, 8** can reliably be prevented.

The remaining ink level judging means **35** judges that the ink remains in large quantities from the fact that the quantity of ink consumed has been reset. The suction mode specifying means **31** outputs to the suction control means **29** a signal indicating a large quantity of ink may be sucked in association with replacement of the ink cartridges. As a result, the suction control means **29** performs suction processing in the large-scale suction mode, which will be described later, and operates the suction timer **39** (**S124**). When the suction timer **39** has measured a predetermined time T1 that is equivalent to the large quantity of ink to be sucked (**S125**), the suction processing is stopped and the suction timer **39** is then reset (**S126**).

Not only is the remaining ink level (at the time the ink has been charged) indicated in relative terms (i.e., in percentage), but the remaining ink level also is controlled based on this percentage until a next replacement of the ink cartridges. By indicating the quantity of ink that is given by subtracting the quantity of ink to be sucked in association with replacement of the ink cartridges as being 100% in this way, the user can be informed of the remaining ink level as correctly as possible.

Further, for the operation of charging the ink into the noncharged recording heads **7, 8** prior to starting up the recording apparatus, i.e., for the so-called initial charging operation, the quantity of ink given by subtracting the quantity of ink to be sucked that is equivalent to the quantity of ink to be initially charged is displayed as being 100%. As a result of this indication, even if there is a difference in the quantity of ink to be consumed for an ink charging operation between ink cartridge replacement after starting up the recording apparatus and first ink cartridge loading at the time of starting up the recording apparatus, the actual remaining ink levels after performing the ink charging operations can be displayed. Thus, the user can be informed of the remaining ink levels more simply, and the indication that the remaining ink level is 100% gives the user a sign that the ink charging operation has been terminated. Hence, the user can recognize the end of the ink charging operation without any special display.

Cleaning Processing

See FIG. **7**. When a cleaning processing command is given by pressing the cleaning switch **30**, the remaining ink level is confirmed through ink consumption check processing (FIG. **9**) to be described later (**S127**), and after the confirmation, it is judged whether or not a printing operation has been performed since the last cleaning processing (**S128**). If no printing operation has been performed since the last cleaning processing, the quantity of ink to be sucked in a very small-scale suction mode is added to the consumption operating means **32** in advance (**S137**), and upon completion of the addition, a sucking operation is performed in the very small-scale suction mode (**S138**).

On the other hand, if a printing operation has been performed since the last cleaning processing, the volume of data printed by such a printing operation is judged (**S129**). If the volume of data printed is large, then, the large-scale suction prohibit mode (**S130**) is released. Then, the quantity of ink to be sucked in the small-scale suction mode is added to the consumption operating means **32** (**S131**). Next, a small-scale sucking operation is performed (**S132**).

If the volume of data printed since the last cleaning processing is found to be small (**S129**), it is judged whether or not the large-scale suction prohibit mode is specified (**S133**). If so, the large-scale suction prohibit mode is released (**S130**), and then the small-scale sucking operation is performed (**S131, S132**).

On the other hand, if the large-scale suction prohibit mode is not specified and if the ink cartridges **9, 10** have plenty of ink, then the number of operations of the cleaning switch **30** in the last cleaning processing is sensed by a cleaning counter or the like. Then, if the cleaning counter indicates a predetermined number, e.g., 3, the cleaning counter is reset to 1. If the cleaning counter indicates a number lower than 3, then, after incrementing the number (**S134**), the quantity of ink to be consumed by large-scale suction is added to the consumption operating means **32** in advance (**S135**), and a sucking operation is performed in the large-scale suction mode (**S136**).

Thus, before suction processing is performed in the very small-scale suction mode, the small-scale suction mode, or in the large-scale suction mode, the quantity of ink to be sucked is added to the consumption operating means **32** in advance. That is, such addition processing precedes the suction processing. Therefore, unlike the case where the quantity of ink to be sucked is added after a sucking operation, even if the power supply or the like is interrupted during the suction processing, the remaining ink level of the ink cartridges **9, 10** can be set to a value on the safety side; i.e., the remaining ink level can conservatively be estimated. Hence, this processing is advantageous in preventing the draining of ink from and the introduction of bubbles into the recording heads **7, 8** due to the ink having been consumed by the suction processing.

Printing Processing

See FIG. **8**. Not only are the type of recording head **7** or **8** and the type of ink to be used for printing judged, but also the print mode is confirmed (**S139**). Also, the quantities of ink to be jetted per droplet both during printing with the specified recording head **7** or **8** and during flushing are set based on the data stored in the coefficient setting means **37** (**S140**).

The quantity of ink to be consumed by the flushing processing before printing which is to be performed prior to a printing operation is added to the ink consumption operating means **32** in advance (**S141**), and the flushing processing before printing is thereafter performed (**S142**).

When the apparatus is ready to print after the preparations for printing have been finished, the average quantity of ink to be consumed per pass of printing, e.g., the quantity of ink equivalent to half the maximum printing volume is added in advance (**S143**). When the printing operation is started (**S144**), the total number of dots per pass is counted (**S145**), and the quantity of ink actually consumed by a single pass of printing is calculated by multiplying the counted total number of dots by the quantity of ink per droplet, and the calculated value is then added (**S146**).

If the remaining ink level is judged to be at the near end level through the ink consumption check processing during printing (**S158** (FIG. **9**)), printing speed is reduced, e.g., by switching to a mode in which a single line of data is printed with a plurality of passes. By reducing the printing speed, in a particular case where the ink cartridges **9, 10** are of such a type that an ink absorbing body is impregnated with ink, the ink absorbing body is prevented from being evacuated to a negative pressure due to the ink therein having been consumed. As a result, the ink present in the regions of the ink cartridges **9, 10** that are remote from the ink discharge ports connected to the recording heads **7, 8** can be allowed to flow into the recording heads **7, 8** reliably, whereby the ink that is running low can more effectively be used up.

Further, if print duty is restricted by the remaining ink level having been judged to be at the suction save level (**S162, S163** (FIG. **9**)), the ink remaining in small quantities in the cartridges **9, 10** can reliably be supplied to the recording heads **7, 8** by reducing the printing speed or by switching to the mode in which a single line of data is printed with a plurality of passes when the data having an extremely heavy print duty such as graphic printing data are to be taken care of.

When the printing operation has lasted for a predetermined time so that the print timer **28** indicates that a periodic flushing operation is required (S (**S147**), the printing operation is suspended and the carriage **1** is moved to the flushing position. Then, the quantity of ink to be jetted by periodic flushing is added to the ink consumption operating means **32** in advance (**S149**), and the flushing processing is performed upon completion of the addition (**S150**).

If printing data is present after the flushing processing has been completed (S148), the aforementioned steps (S145) through (S150) are repeated to perform the printing operation.

When all the printing data is printed (S148), the quantity of ink added in advance in step (S143) is subtracted (S151), and the quantity of ink to be jetted by flushing is added to the ink consumption operating means 32 in advance (S152), and flushing processing (as printing operation termination processing) is performed (S153). Then, the apparatus waits for a next input of printing data.

Thus, a printing operation is performed after adding the average quantity of ink to be consumed by a single pass of printing prior to initiating the printing operation, and then the quantity of ink added in advance as an estimate is subtracted upon end of the single pass of printing. Therefore, by doing so, the quantity of ink actually consumed that cannot be added unless the single pass of printing is terminated can be added in the form of an equivalent quantity even if such addition cannot be made due to the power supply having been turned off. As a result, the remaining ink level in the ink cartridges can be estimated to a value as close to the actual value as possible, so that a possible running out of the ink during printing can be precluded.

Ink Consumption Check Processing

See FIG. 9. The remaining ink level of the loaded ink cartridges 9, 10 is calculated by taking into account the product of the elapsed time from the timing at which the cartridges 9, 10 for which the load timer 23 is operating have been loaded and the evaporation rate per unit time of an ink solvent from the cartridges 9, 10, the ink tubes, and the like (S154).

If a cleaning processing command has not been given before step S155, the remaining ink level is compared with ink end judgment reference levels (S156). If the remaining ink level is judged to be at the ink end level, a message to that effect is displayed on the display means 38 (S157), and there is provided a prompt to replace the ink cartridges 9, 10. If the remaining ink level is judged to be between the ink end level and the near end level (S158), then a message "near end level" is displayed on the display means 38 (S159). Further, if the remaining ink level is judged to be over the near end level and at the large-scale suction prohibit level (S160), then the large-scale suction prohibit mode is specified (S161) so as to prevent the ink from inadvertently being consumed in large quantities by cleaning.

Still further, if it is judged that the remaining ink level in the cartridges 9, 10 is somewhat low so that smooth ink supply at a normal ink sucking speed within the ink absorbing body might be interrupted although the ink can be sucked for cleaning (S162), the quantity of ink to be sucked is restricted, and the so-called duty also is restricted (S163), the duty being the number of dots to be printed per unit time during printing. In cases other than the above, it is judged that the ink cartridges 9, 10 have ink necessary and sufficient for normal operation (S164).

If the cleaning switch 30 has already been pressed prior to the ink consumption check processing (S155), it is judged before cleaning whether the remaining ink level is at the ink end level by comparing the remaining ink level with the ink end judgment level so that the apparatus gets ready for consuming ink for cleaning (S165). If it is judged that the remaining ink level is below the ink end level according to such judgment level, then the remaining ink level is judged to be at the ink end level even if a printing operation can be performed at such remaining ink level, and a message "ink end level" is displayed on the display means 38 (S157), and replacement of the ink cartridges 9, 10 is prompted before cleaning. As a result, substantially all the ink in the ink cartridges 9, 10 can be consumed, and hence a possible running out of ink from the recording heads 7, 8 can be precluded. If the remaining ink level is judged to be more than the ink end level, the aforementioned steps (S158) through (164) are performed.

While the large-scale suction processing and the small-scale suction processing are performed by a single suction mode in the aforementioned embodiment, the suction mode may be altered in accordance with the remaining ink levels. That is, as shown in FIG. 10 and FIG. 11, the quantities of ink to be sucked by suction-processing are set to the consumption operating means 32 in advance (FIG. 10 (S166), FIG. 11 (S171)), and then it is judged whether or not the suction save mode is specified (FIG. 10 (S167), FIG. 11 (S172)). If the suction save mode is not specified, a first large-scale sucking operation (FIG. 10 (S168)) or a first small-scale sucking operation (FIG. 11 (S173)) is performed through a normal sucking operation, the first sucking operations sucking the specified quantity of ink.

On the other hand, if the suction save mode is specified while the remaining ink level is judged to be at the suction save level by the ink consumption check processing (FIG. 9) due to the ink in the ink cartridges 9, 10 having been reduced (FIG. 10 (S167), FIG. 11 (S172)), the suction save mode is released (FIG. 10 (S169), FIG. 11 (S174)), and a second large-scale sucking operation (FIG. 10 (S170)) or a second small-scale sucking operation (FIG. 11 (S175)) for sucking the added quantity of ink may be performed by suppressing the flow of ink during sucking while reducing the numbers of revolutions of the pumps 16, 17, driving the pumps 17, 18 intermittently, or the like.

Thus, the flow of ink to be sucked is suppressed without changing the quantity of ink needed for large-scale suction or small-scale suction. By doing so, in a particular case where an ink cartridge is of such type that an ink absorbing body made of a porous elastic body or the like is impregnated with ink, the quantity of ink needed for cleaning processing can be discharged while preventing interruption of the smooth flow of ink within the ink absorbing body. If the ink is running low, the quantity of ink needed for printing can be fed to the recording heads 7, 8 without interrupting smooth flow of ink within the ink absorbing body by reducing the printing speed. Therefore, the cartridges 9, 10 whose ink is running low can be consumed without being wasted.

While an example of a recording apparatus capable of effecting monochromatic and color printing by mounting two types of ink cartridges, one for black ink and the other for color inks, has been described in the aforementioned embodiment, it is apparent that similar advantages can be provided when the invention is applied to-recording apparatuses dedicated to only monochromatic printing.

Further, while an example of a recording apparatus that mounts ink cartridges on the carriage has been described in the aforementioned embodiment, it is apparent that similar advantages can be provided when the invention is applied to recording apparatuses in which an ink cartridge is accommodated in a casing and the ink is supplied to the recording head through a passage forming means such as a tube.

TABLE 1

QUANTITY BY WEIGHT OF INK PER INK DROPLET FOR PRINTING

	WEIGHT (ng)		
MODE	COLOR	BLACK 1	BLACK 2
HIGH-DEFINITION PRINT MODE	25	60	20

TABLE 1-continued

QUANTITY BY WEIGHT OF INK PER INK DROPLET FOR PRINTING

MODE	WEIGHT (ng) COLOR	BLACK 1	BLACK 2
NORMAL PRINT MODE	50	130	50
DRAFT PRINT MODE	60	120	55

TABLE 2

QUANTITY BY WEIGHT OF INK PER INK DROPLET FOR FLUSHING

MODE	WEIGHT (ng) COLOR	BLACK 1	BLACK 2
PRE-PRINTING FLUSHING PERIODIC FLUSHING	55	140	54
HIGH-DEFINITION PRINT MODE	25	60	20
NORMAL PRINT MODE	50	130	50
DRAFT PRINT MODE	60	120	55
PRE-ENDING FLUSHING	60	150	58

TABLE 3

JUDGMENT LEVEL

JUDGMENT LEVEL	REMAINING INK LEVEL (%)
INK END	0
INK END BEFORE CLEANING	1~5
NEAR END	2~20
LARGE-SCALE SUCTION PROHIBIT	2~25
SUCTION PROHIBIT	2~30

There is claimed:

1. An ink jet recording apparatus comprising:
an ink jet recording head for jetting an ink droplet in accordance with printing data;
an ink cartridge supplying ink to said recording head;
capping means for sealing said recording head;
a suction pump for evacuating said capping means to a negative pressure;
suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump; and
remaining ink level judging means for controlling a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head;
wherein said remaining ink level judging means adds a quantity of ink to be discharged by said suction processing as a quantity of ink consumed, said addition being made before said suction processing is performed.

2. An ink jet recording apparatus according to claim 1, wherein:
said suction processing is intermittently performed a plurality of times; and
a quantity of ink to be discharged by said sucking operation in said plurality of times is added as a quantity of ink consumed before starting to perform said sucking operation said plurality of times.

3. An ink jet recording apparatus according to claim 1, further comprising:
flushing means for jetting an ink droplet to prevent said recording head from clogging, wherein
a quantity of ink to be discharged by flushing processing being added as a quantity of ink consumed before said flushing processing is performed.

4. An ink jet recording apparatus according to claim 3, further comprising means for setting a quantity of ink to be jetted per ink droplet during said flushing processing.

5. An ink jet recording apparatus according to claim 1, further comprising means for reducing a printing speed when a remaining ink level judged by said remaining ink level judging means is equal to or smaller than a predetermined value.

6. An ink jet recording apparatus comprising:
an ink jet recording head for jetting an ink droplet in accordance with printing data;
an ink cartridge supplying ink to said recording head;
capping means for sealing said recording head;
a suction pump for subjecting said capping means to a negative pressure;
suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump; and
remaining ink level judging means for judging a remaining ink level of said ink cartridge, wherein said remaining ink level judging means adds a quantity of ink to be discharged by said suction processing as a quantity of ink consumed before said suction processing is performed;
and wherein when said remaining ink level is equal to or smaller than a predetermined value, said suction control means limits a quantity of ink to be sucked.

7. An ink jet recording apparatus according to claim 6, further comprising:
flushing means for jetting an ink droplet to prevent said recording head from clogging, wherein
a quantity of ink to be discharged by flushing processing being added as a quantity of ink consumed before said flushing processing is performed.

8. An ink jet recording apparatus according to claim 7, further comprising means for setting a quantity of ink to be jetted per ink droplet during said flushing processing.

9. An ink jet recording apparatus according to claim 6, further comprising means for setting a print duty based on said remaining ink level judged by said remaining ink level judging means.

10. An ink jet recording apparatus according to claim 6, further comprising means for reducing a printing speed when a remaining ink level judged by said remaining ink level judging means is equal to or smaller than a predetermined value.

11. An ink jet recording apparatus comprising:
an ink jet recording head for jetting an ink droplet in accordance with printing data;
an ink cartridge supplying ink to said recording head;
capping means for sealing said recording head;
a suction pump for evacuating said capping means to a negative pressure;
suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level judging means for judging a remaining ink level of said ink cartridge; and

means for setting a print duty based on said remaining ink level judged by said remaining ink level judging means;

wherein when said remaining ink level is equal to or smaller than a predetermined value, said suction control means limits an ink sucking speed.

12. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head; and

remaining ink level judging means for adding a quantity of ink to be jetted out of said recording head, based on said printing data, every predetermined printing operation of said recording head.

13. An ink jet recording apparatus according to claim **12**, wherein said remaining ink level judging means adjusts a quantity of ink to be jetted per ink droplet during printing so as to correspond to a printing mode.

14. An ink jet recording apparatus according to claim **12**, wherein:

said remaining ink level judging means adds a quantity of ink to be consumed per pass in advance of starting a printing operation; and

subtracts said added quantity of ink after having terminated printing of a single pass.

15. An ink jet recording apparatus according to claim **12**, further comprising:

flushing means for jetting an ink droplet to prevent said recording head from clogging; and

a quantity of ink to be discharged by flushing processing being added as a quantity of ink consumed before said flushing processing is performed.

16. An ink jet recording apparatus according to claim **15**, further comprising means for setting a quantity of ink to be jetted per ink droplet during said flushing processing.

17. An ink jet recording apparatus according to claim **12**, further comprising means for setting a print duty based on said remaining ink level judged by said remaining ink level judging means.

18. An ink jet recording apparatus according to claim **12**, wherein said quantity of ink to be jetted per ink droplet is changed in accordance with the ink temperature.

19. An ink jet recording apparatus according to claim **12**, further comprising means for reducing a printing speed when a remaining ink level judged by said remaining ink level judging means is equal to or smaller than a predetermined value.

20. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping means for sealing said recording head;

a suction pump for subjecting said capping means to a negative pressure;

suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level judging means for controlling a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head; and

means for relatively displaying said remaining ink level as being full, after performing said suction processing when a new ink cartridge has been loaded to said recording head;

wherein said remaining ink level judging means adds a quantity of ink to be discharged by said suction processing, as a quantity of ink consumed, before said sucking operation is performed.

21. An ink jet recording apparatus according to claim **20**, wherein said remaining ink level is displayed on a host computer.

22. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

remaining ink level judging means for adding a quantity of ink to be jetted out of said recording head, based on said printing data, every time said recording head performs a predetermined printing operation; and

load time detecting means for detecting an integrated time for which said ink cartridge has been loaded to said recording head;

wherein said remaining ink level judging means judges and displays said remaining ink level taking into account a quantity of ink evaporated from said ink cartridge based on said integrated time.

23. An ink jet recording apparatus according to claim **22**, wherein said remaining ink level is displayed on a host computer.

24. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping means for sealing said recording head;

a suction pump for evacuating said capping means to a negative pressure;

suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump; and

remaining ink level judging means for controlling a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head;

wherein said remaining ink level judging means has at least two judgement levels, including an ink end judgement level used during printing and an ink end judgment level used before performing said sucking operation.

25. An ink jet recording apparatus according to claim **24**, wherein said remaining ink level judging means further includes a third judgment level substantially the same as said ink end judgment level immediately before performing said suction processing, said third judgment level defining an ink near end judgment level used during printing.

26. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

remaining ink level judgment means for adding a quantity of ink to be jetted out of said recording head based on printing data every time said recording head performs a predetermined printing operation; and

ink cartridge replacement detecting means for detecting replacement of said ink cartridge;

wherein when a remaining ink level is lower than a second ink end level that is slightly higher than an ink end judgment level, said remaining ink level judging means

is reset by a signal from said ink cartridge replacement detecting means.

27. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping means for sealing said recording head;

a suction pump for evacuating said capping means to a negative pressure;

suction control means for controlling suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level judging means for managing a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head and adding a quantity of ink to be jetted out of said recording head based on said printing data every time said recording head performs a predetermined printing operation; and

ink cartridge replacement detecting means for detecting replacement of said ink cartridge;

wherein said remaining ink level judging means has at least three judgment levels, including a first ink end judgment level used during printing; a second ink end judgment level used before performing said sucking operation; and a third ink end judgment level slightly higher than said first ink end judgment level, and

wherein when said remaining ink level is below said third ink end judgment level, said remaining ink level judgment means is reset by a signal from said ink cartridge replacement detecting means.

28. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump; and

remaining ink level judging controller which controls a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head;

wherein said remaining ink level judging controller adds a quantity of ink to be discharged by said suction processing as a quantity of ink consumed, said addition being made before said suction processing is performed.

29. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump; and

remaining ink level detector which judges a remaining ink level of said ink cartridge, wherein said remaining ink level detector adds a quantity of ink to be discharged by said suction processing as a quantity of ink consumed before said suction processing is performed;

and wherein when said remaining ink level is equal to or smaller than a predetermined value, said suction controller limits a quantity of ink to be sucked.

30. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level detector which judges a remaining ink level of said ink cartridge; and

controller which sets a print duty based on said remaining ink level judged by said remaining ink level detector;

wherein when said remaining ink level is equal to or smaller than a predetermined value, said suction controller limits an ink sucking herein.

31. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head; and

remaining ink level judging controller which adds a quantity of ink to be jetted out of said recording head, based on said printing data, every predetermined printing operation of said recording head.

32. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level judging controller which controls a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head; and

display which relatively displays said remaining ink level as being full, after performing said suction processing when a new ink cartridge has been loaded to said recording head;

wherein said remaining ink level judging controller adds a quantity of ink to be discharged by said suction processing, as a quantity of ink consumed, before said sucking operation is performed.

33. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

remaining ink level judging controller which adds a quantity of ink to be jetted out of said recording head, based on said printing data, every time said recording head performs a predetermined printing operation; and

load time detector which detects an integrated time for which said ink cartridge has been loaded to said recording head;

wherein said remaining ink level judging controller judges and displays said remaining ink level taking into

account a quantity of ink evaporated from said ink cartridge based on said integrated time.

34. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump; and

remaining ink level judging controller which controls a quantity of ink in said ink cartridge by integrating quantities of ink discharged from said recording head;

wherein said remaining ink level judging controller has at least two judgment levels, including an ink end judgment level used during printing and an ink end judgment level used before performing said sucking operation.

35. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

remaining ink level judging controller which adds a quantity of ink to be jetted out of said recording head based on said printing data, every time said recording head performs a predetermined printing operation; and

ink cartridge replacement detector which detects replacement of said ink cartridge;

wherein when said remaining ink level is lower than a second ink end level that is slightly higher than an ink end judgment level, said remaining ink level judging controller is reset by a signal from said ink cartridge replacement detector.

36. An ink jet recording apparatus comprising:

an ink jet recording head for jetting an ink droplet in accordance with printing data;

an ink cartridge supplying ink to said recording head;

capping unit which seals said recording head;

a suction pump for subjecting said capping unit to a negative pressure;

suction controller which controls suction processing for discharging said ink by sucking said recording head with said suction pump;

remaining ink level judging controller which manages a quantity of ink in said link cartridge by integrating quantities of ink discharged from said recording head and adding a quantity of ink to be jetted out of said recording head based on said printing data every time said recording head performs a predetermined printing operation; and

ink cartridge replacement detector which detects replacement of said ink cartridge;

wherein said remaining ink level judging controller has at least three judgment levels, including a first ink end judgment level used during printing; a second ink end judgment level used before performing said sucking operation; and a third ink end judgment level slightly higher than said first ink end judgment level, and

wherein when said remaining ink level is below said third ink end judgment level, said remaining ink level judging controller is reset by a signal from said ink cartridge replacement detector.

* * * * *

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United States Patent [19]

Barton et al.

[11] Patent Number: 5,710,581

[45] Date of Patent: Jan. 20, 1998

[54] **INKJET PRINTHEAD HAVING INTERMITTENT NOZZLE CLEARING**

[75] Inventors: **Earl L. Barton**, Corvallis, Oreg.; **Thomas J. Purwins**, Vancouver, Wash.

[73] Assignee: **Hewlett-Packard Company**, Palo Alto, Calif.

[21] Appl. No.: **283,318**

[22] Filed: **Jul. 29, 1994**

[51] **Int. Cl.**[6] **B41J 2/165**

[52] **U.S. Cl.** **347/35**; 347/19

[58] **Field of Search** 347/23, 19, 35, 347/60, 14

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,791,434	12/1988	Smith et al.	347/35
4,977,459	12/1990	Ebinuma et al.	358/296
5,109,234	4/1992	Otis, Jr. et al.	347/14
5,185,615	2/1993	Koitabashi et al.	347/35
5,187,500	2/1993	Bohorques et al.	347/56
5,428,380	6/1995	Ebisawa	347/19

OTHER PUBLICATIONS

Michael T. Dangelo, et al., "Print Cartridge Fixturing and Maintenance in the HP DeskJet 1200 C Printer", Hewlett-Packard Journal, Feb. 1994, vol. 45, No. 1, pp. 67–71.

William S. Colburn et al., "Automated Assembly and Testing of HP DeskJet 1200 C Print Cartridges", Hewlett-Packard Journal, Feb. 1994, vol. 45, No. 1, pp. 79–84.

Hewlett-Packard Company, "HP DeskWriter 560C Users Guide", Manual No. C2169-90010, Dec. 1993, p. 4–11.

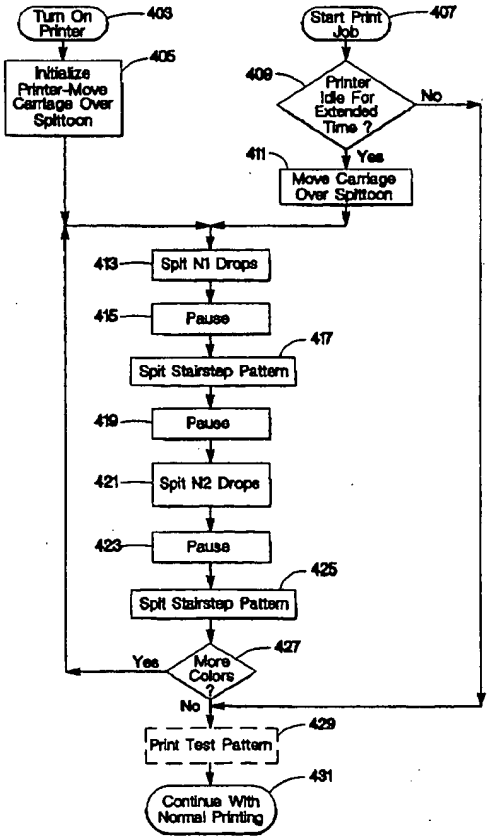
Hewlett-Packard Company "HP Deskwriter 560C Setup Guide", Manual No. C2169-90036, Dec. 1993, p. 17.

Primary Examiner—John E. Barlow, Jr.

[57] **ABSTRACT**

A method and apparatus clears blocked nozzles in an inkjet primer printhead by placing the printhead in a position relative to a service station such that ink which is expelled from the nozzles is captured without reaching the medium upon which printing is to occur. Ink is expelled for a first time segment from each nozzle in a first pattern for a number of nozzle expulsions. Following the first time segment, a pause period is entered. Following the pause, ink is expelled in a second time segment from each nozzle in a second pattern for a second number of nozzle expulsions before the printer enters the print status mode.

24 Claims, 6 Drawing Sheets



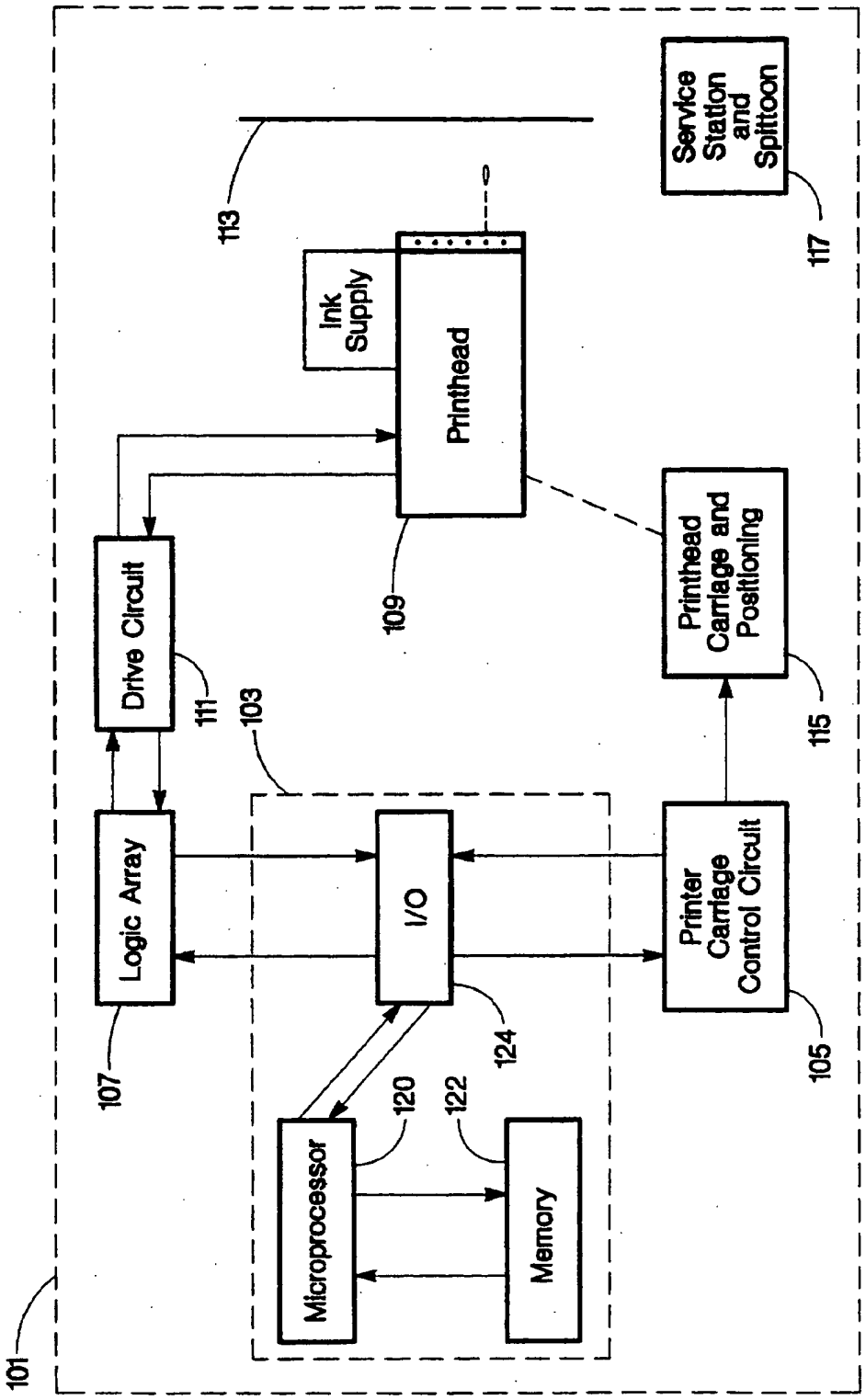

Service Station and Spittoon
117
113
Ink Supply
Printhead
109
Drive Circuit
111
103
Printhead Carriage and Positioning
115
Logic Array
I/O
Printer Carriage Control Circuit
107
124
105
120
122
Microprocessor
Memory
101

Fig. 1

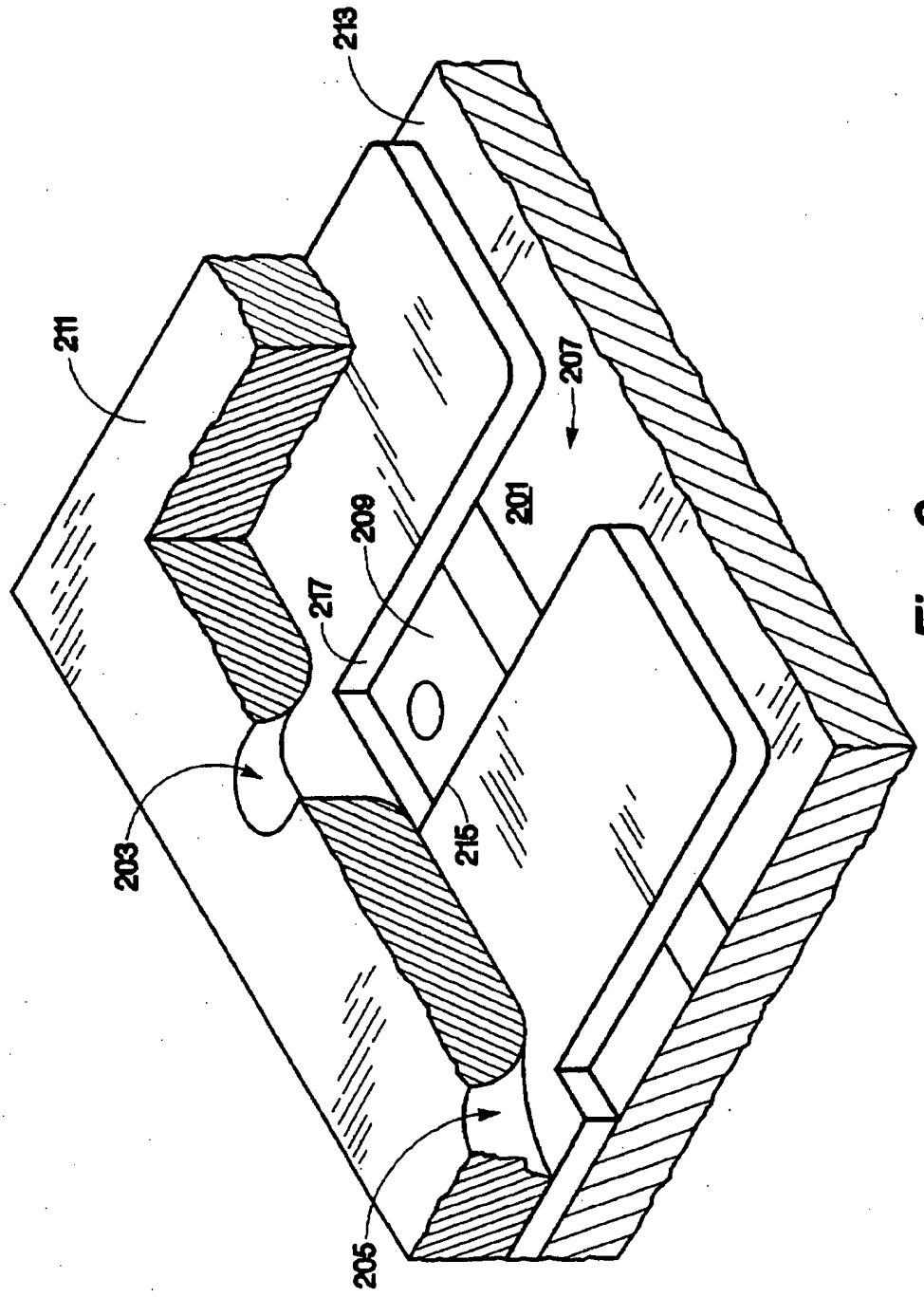


Fig. 2

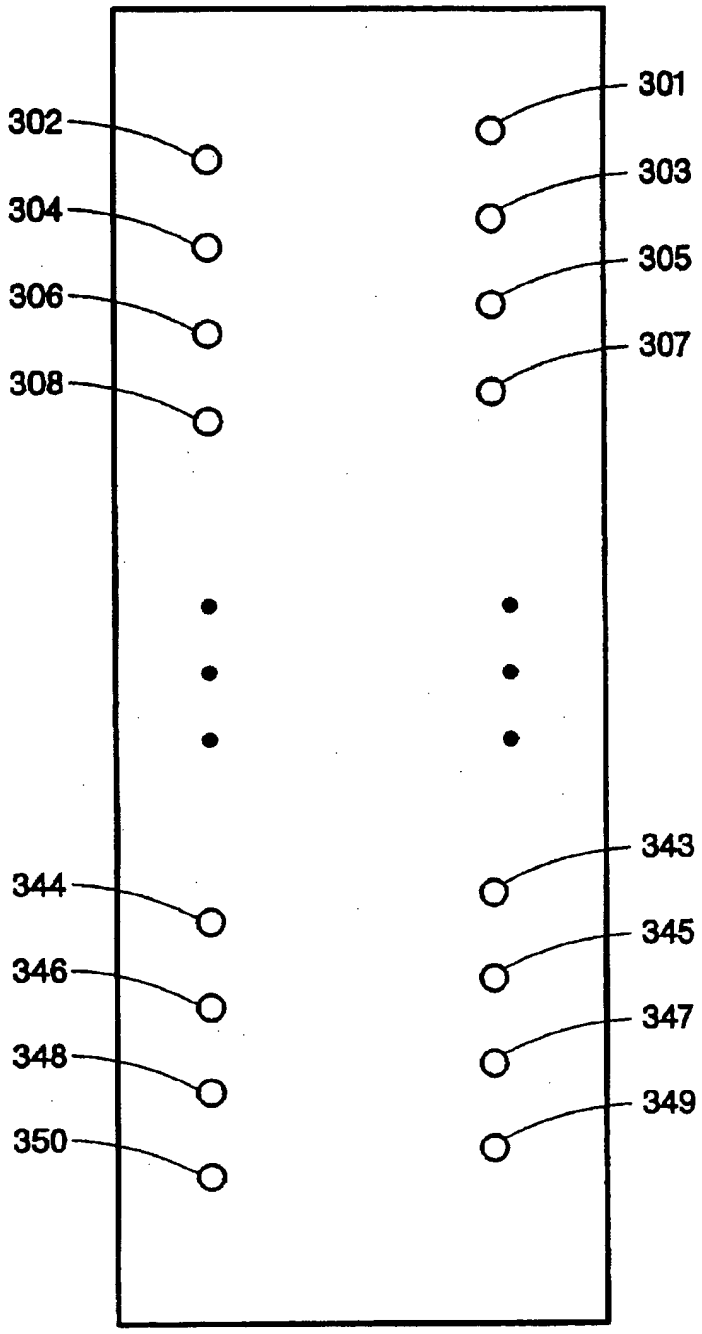


Fig. 3

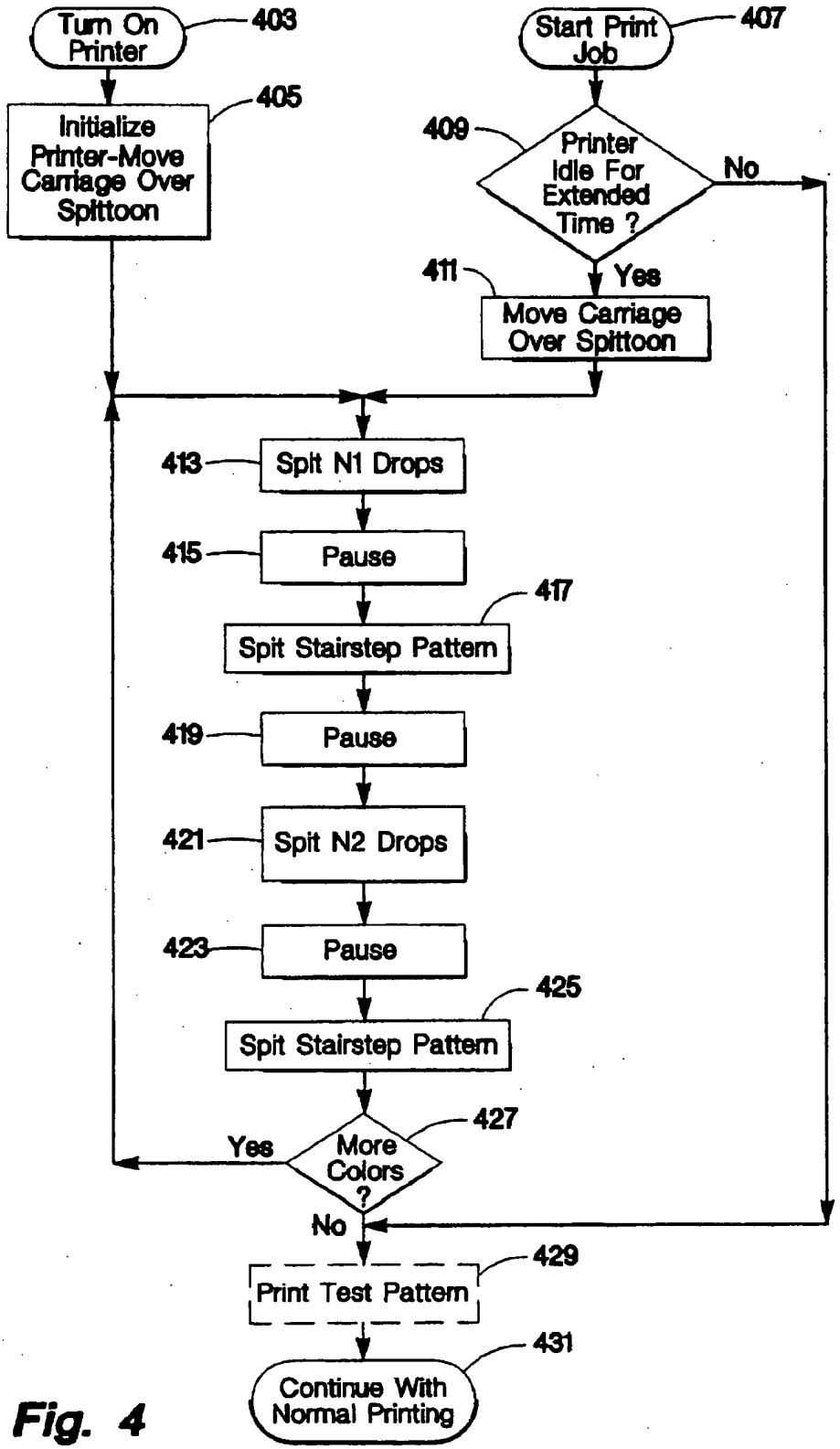

Turn On Printer
403
Initialize Printer-Move Carriage Over Spittoon
405
Start Print Job
407
409
Printer Idle For Extended Time ?
No
Yes
411
Move Carriage Over Spittoon
413
Spit N1 Drops
415
Pause
417
Spit Stairstep Pattern
419
Pause
421
Spit N2 Drops
423
Pause
425
Spit Stairstep Pattern
427
Yes
More Colors ?
No
429
Print Test Pattern
431
Continue With Normal Printing

Fig. 4

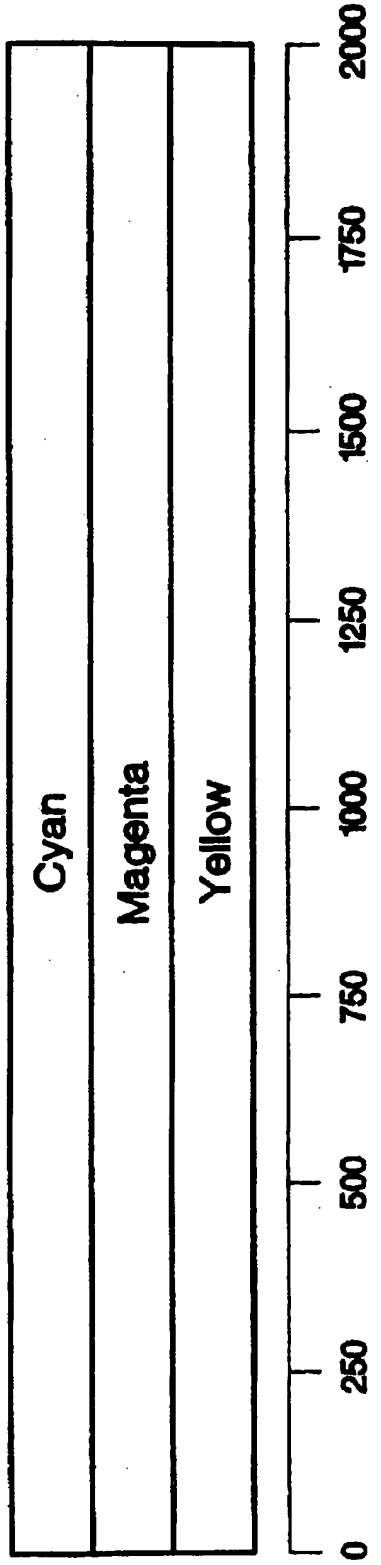
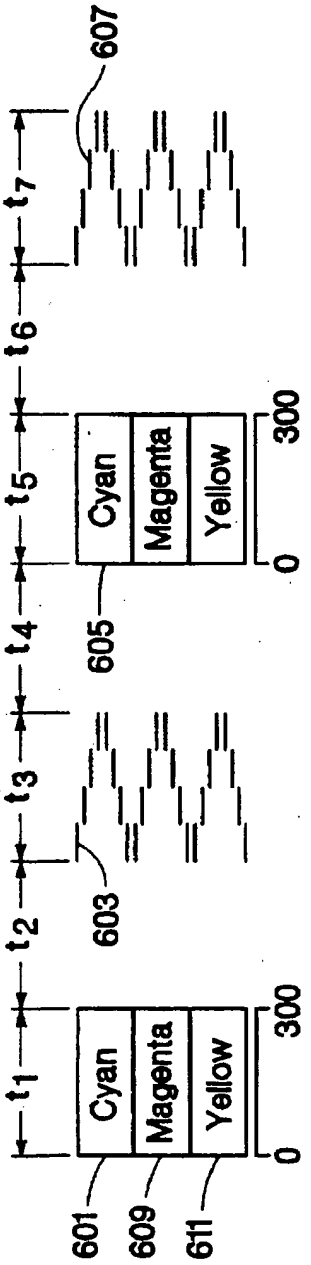


Fig. 5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t4
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t7
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Yellow
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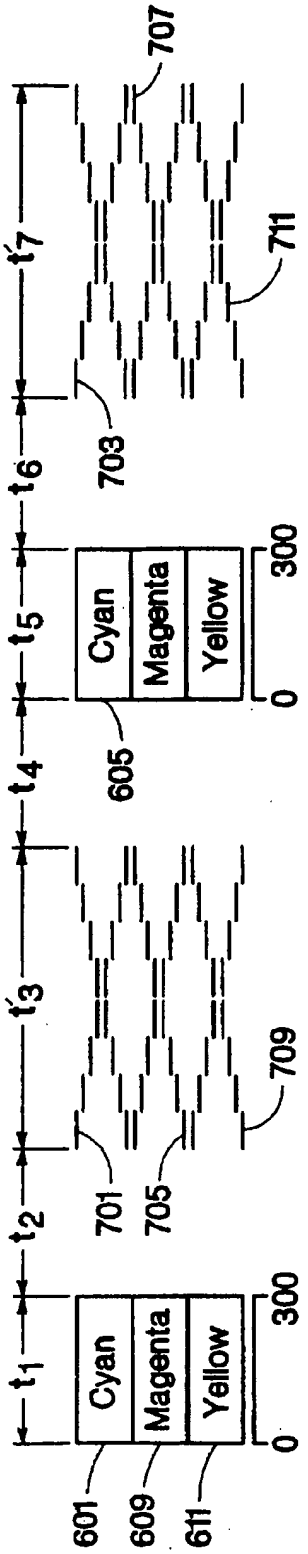
0
601
609
611
603
605
607

Fig. 6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t'3
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t5
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t'7
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Magenta
Yellow
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601
609
611
701
705
709
605
703
707
711

Fig. 7

INKJET PRINTHEAD HAVING INTERMITTENT NOZZLE CLEARING

FIELD OF THE INVENTION

The present invention relates to a printhead for an inkjet printer and more specifically relates to the method and apparatus for clearing blocked nozzles of a printhead employed by a thermal inkjet printer.

BACKGROUND OF THE INVENTION

Thermal inkjet printers operate by expelling a small volume of ink through a plurality of small nozzles or orifices in a surface held in proximity to a medium upon which marks or printing is to be placed. These nozzles are arranged in a fashion in the surface such that the expulsion of a droplet of ink from a determined number of nozzles relative to a particular position of the medium results in the production of a portion of a desired character or image. Controlled repositioning of the substrate or the medium and another expulsion of ink droplets continues the production of more pixels of the desired character or image. Inks of selected colors may be coupled to individual arrangements of nozzles so that selected firing of the orifices can produce a multicolored image by the inkjet printer.

Expulsion of the ink droplet in a conventional thermal inkjet printer is a result of rapid thermal heating of the ink to a temperature which exceeds the boiling point of the ink solvent and creates a gas phase bubble of ink. Each nozzle is coupled to a small unique firing chamber filled with ink and having an individually addressable heating element resistor in thermal contact with the ink. As the bubble nucleates and expands, it displaces a volume of ink which is forced out of the nozzle and deposited on the medium. The bubble then collapses and the displaced volume of ink is replenished from a larger ink reservoir by way of ink feed channels.

The ink is composed of many chemical constituents, some of which are necessarily volatile for proper drying when the ink droplet is placed on the printed medium. This volatility, however, results in a drying and crusting of ink in and around the nozzle as well as an increased viscosity of the ink in the firing chamber and the associated ink feed channels over a period of time during which the nozzle is not used. To slow the undesired drying of ink, the nozzles are capped during periods of nonuse. Also, as part of a maintenance program for printheads which have not been used for a period of time and for new printheads, the printer is programmed to transport the printhead to a component known as a service station and cause the printhead to spit ink from each nozzle into a spittoon to attempt to clear clogged nozzles and to remove higher viscosity ink from the firing chamber. In some printers, a vacuum system aids in the clearing of nozzles. When a nozzle or its associated ink feed channel becomes plugged or encrusted with dried ink, the amount of ink ejected when a firing pulse is applied to the heater resistor is unpredictable and may be nil. A nozzle ejecting little or no ink produces a noticeable gap in the printed characters or a stripe or band in a solid print path such as might be encountered when a graphics or picture is printed. This gap or band is very undesirable from the standpoint of the user of a printer who expects whole characters and unstriped, solid graphics.

It is well known that ink droplet volume is related, among other things, to the viscosity of the ink. To provide uniformity of droplet volume, the ink is prewarmed in some inkjet printers in the proximity of the nozzles by a series of

electrical pulses applied to the resistors which form the ink heating elements. These warming pulses do not contain enough energy to cause the ink to boil (as a firing pulse would) but do provide localized heating to the ink to make the ink viscosity more uniform. This more uniform ink viscosity provides better printing quality by providing a uniformity of ink volume expelled upon the activation of a heater resistor. Such prewarming of ink prior to printing is further discussed in U.S. Pat. No. 5,109,234.

The foregoing efforts to improve the quality of print from an inkjet printhead have resulted in a recognized high quality of performance from the inkjet printhead. Nevertheless, a desire for improved quality of print remains the goal of printhead designers.

SUMMARY OF THE INVENTION

A method and apparatus which clears blocked nozzles in an inkjet printer printhead encompasses the expulsion of ink for a first time segment from a group of nozzles in a first pattern for a number of nozzle expulsions. Following the first time segment, a pause period is entered for a period of time. Ink is expelled in a second time segment following the pause period from the group of nozzles in a second pattern for a second number of nozzle expulsions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an inkjet printer which may employ the present invention.

FIG. **2** is an isometric view of a portion of a thermal inkjet printhead for a print cartridge for the printer of FIG. **1**.

FIG. **3** is a magnified view of a printhead orifice plate which may be used in the print cartridge for the printer of FIG. **1**.

FIG. **4** is a flowchart of the process of pulse spitting from the printhead of the inkjet printer of FIG. **1**.

FIG. **5** is a graphic representation of printhead ink output using a conventional spitting nozzle clearing process.

FIG. **6** is a graphic representation of printhead ink output from a printhead spitting nozzle clearing process employing the present invention.

FIG. **7** is a graphic representation of printhead ink output from a printhead employing an alternative nozzle clearing process of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

A basic block diagram of a printer which may employ the present invention is shown in FIG. **1**. Such a printer may be a model DeskJet 560C manufactured by Hewlett-Packard Company or similar product. Included in such a printer as that shown in the block diagram as block **101**, is an electronic processor **103** which communicates with a conventional printer carriage control circuit **105** and a logic array circuit **107** which controls printhead firing. In a conventional logic array **107**, the output from the processor **103** is multiplexed into a reduced number of electrical interconnect lines to the printhead. A print cartridge **109**, which may be a model HP 51626A for black ink printing or a model HP 51625A for color printing available from Hewlett-Packard Company or similar print cartridge and suitable for use with the DeskJet 560C printer model, includes and ink supply and an orifice plate. An electronic drive circuit **111** interfaces between the logic array **107** and the printhead **109** and produces a demultiplexed electrical output firing pulse of a predetermined energy to each of the

selected thin film heater resistors to boil the ink in a firing chamber and expel the ink from one nozzle. The print cartridge **109** is positioned relative to a medium **113** Upon which characters or objects are to be printed by means of a conventional printhead carriage and positioning function **115**.

A service station **117** is used to maintain the cleanliness of the printhead. Typically, the service station **117** is physically located to one side of the medium **113** in the printer and is usually the parking place for the printhead when the printhead is not in use. A capping mechanism, not shown, covers the orifices (nozzles) and maintains a relatively high humidity in the area around the nozzles. Included in the service station is a wiping mechanism which clears debris from the orifice plate without scratching the plate. Also included in the service station is a small reservoir for collecting ink which is expelled during a process of clearing the nozzles of dried ink and other particles. Because of its function, this reservoir has become known as a spittoon.

The processor **103** of the printer of FIG. **1** includes a microprocessor **120** which is a conventional microprocessor device which may also be integrated with additional circuitry in a larger, custom, integrated circuit. Associated ROM memory **122** and interface (I/O) circuitry **124** are included in the processor **103**. Stored in the memory **122** are several processes in computer readable form and relating to the operation of the printer. When accessed by the microprocessor **120**, these processes are performed in sequence by the microprocessor. In the preferred embodiment, a process of nozzle clearing is generated from the stored commands and executed by the microprocessor **120** through the I/O **124** and the printer carriage and printhead. When the need for clearing nozzles is determined, the print cartridge is positioned in line with the spittoon of the service station **117** and a series of ink droplets are expelled from each nozzle for each color of ink. The need for a clearing of the nozzles, in the preferred embodiment, includes a determination of how long it has been since the nozzles were last fired. If this amount of time exceeds 18 hours, the process of nozzle and ink path clearing is activated. Other nozzle clearing methods may be initiated earlier than 18 hours in an alternative embodiment. Also, if the printer has just been turned on or the print cartridge is a new cartridge, the clearing process is activated. Logic array **107** is a conventional electronic circuit which addresses each nozzle and which controls the firing pulse to each resistor associated with the nozzle.

FIG. **2** is an isometric view of a portion of a typical thermal inkjet printhead illustrating an ink firing chamber **201** and an nozzle (orifice) **203** associated with the ink firing chamber **201**. Part of a second nozzle **205** associated with another ink firing chamber is also shown. Many nozzles are typically arranged in a predetermined pattern on the orifice plate so that the ink which is expelled from selected nozzles creates a defined pattern of print on the medium. Ink is supplied to the firing chamber **201** via an opening **207** to replenish ink which has been expelled from nozzle **203** when ink has been vaporized by localized heating from a thin film resistor heating structure **209**. The ink firing chamber is bounded by walls created by the orifice plate **211**, a layered silicon substrate **213**, and walls **215**, **217** created by a polymer ink barrier layer. A printhead which would be employed in a printer such as a DeskJet 560C would have **50** nozzles (and associated ink firing chambers and thin film heater resistors) in an orifice plate (and substrate) having approximate dimensions of 5.4 mm by 7.7 mm.

A front view of an orifice plate is depicted in FIG. **3**. For simplicity, only sixteen nozzles **301–308**, **343–350** are shown. Other printheads may have more or fewer nozzles, arrangements of nozzles in other than two columns, and/or nozzle offsets from a straight columnar line. For example, a print cartridge which is capable of multiple color printing may have three groups of two eight nozzle columns for each group, each group being supplied a different color ink from separate ink reservoirs. Nevertheless, each nozzle has a thin film heater resistor which is relatively independently addressable from the logic array and therefore is capable of ejecting ink from the associated nozzle upon command.

It has been recognized that nozzles can become entrusted with dried ink or plugged with foreign objects and debris such as paper fibers. Furthermore, the ink channels can become blocked with viscous or dried ink as well as foreign objects. Nozzle and ink path clearing is accomplished by a process commonly known as spitting. Conventionally, a printhead is positioned relative to the spittoon such that ink of one color is simultaneously ejected from each nozzle into the spittoon for a number of ejections. This spitting is repeated for each color ink. While this process has proven to be effective, a better process is to discontinuously eject ink from the nozzles. The flowchart of FIG. **4** illustrates the process of intermittent/discontinuous spitting to clear nozzles and ink paths.

Two potential starting points exist for the process of clearing printheads in the preferred embodiment of the present invention. First, when the printer is turned "on" (which in addition to the obvious, also occurs when a new cartridge is inserted into the printer or when the printer is manually commanded to enter a nozzle-clearing mode), at **403**, the printer is initialized, at **405**, and the carriage containing the printhead is located over the spittoon in anticipation of the ink to be expelled. In the second starting condition, which is upon the start of a print job, at **407**, a determination is made whether the printer has been idle for an extended period of time, at **409**. In the preferred embodiment, an extended period of time is in the order of 18 hours of non-printing operation. If the extended period of time value has been exceeded, the carriage containing the printhead is positioned over the spittoon, at **411**, for the forthcoming expulsion of ink droplets. The logic array **107** is commanded by the microprocessor **120** to spit droplets of ink from each orifice simultaneously N_i times in a first burst, at **413**. If the printhead has multicolor capability, only one color of ink is expelled at a single time in the preferred embodiment. However, all the nozzles may spit ink simultaneously regardless of which color ink is associated with a particular group of nozzles in an alternative embodiment. Expulsion of ink is ceased for a pause period of 0.1 seconds, at **415**. The microprocessor then commands the logic array to activate the heater resistors of the printhead in a stairstep pattern, at **417**, in a manner which causes two printhead nozzles to print simultaneously and sequences to each of a pair of nozzles in turn. Referring again to FIG. **3**, the nozzles of the printhead orifice plate are caused to fire in a pattern commencing at opposite ends of the printhead and in opposing columns. That is, starting with nozzles **301** and **350**, continuing with nozzles **302** and **349**, then nozzles **303** and **348**, and so forth until each nozzle has spit twenty ink droplets. Depending upon the number of nozzles and other parameters, the stairstep firing pattern may be repeated one or more times. If the nozzles are arranged in color-associated groups, each group of nozzles fires in the foregoing stairstep pattern. Following the stairstep spiring pattern, the process again pauses, at **419**, for a period of time equal to 0.1 seconds. Simultaneous ink expulsion from each nozzle (associated with one ink color) N_2 times in a second burst is

commanded at **412**. A pause of 0.1 seconds is made at **423** and a second stairstep expulsion is made at **425**. In the preferred embodiment, $N_1=N_2=300$. Steps **413** through **425** may be repeated as necessary for a given color and this repeat may be sequential or be interdigitated with expulsions of other colors. If the print cartridge contains multiple colors of ink, a determination is made in the preferred embodiment, at **427**, that the discontinuous ink spitting process should be performed again for the next color ink. Thus, steps **413** through **425** are repeated for the next ink color until all the ink colors have had the associated nozzles cleared. At the option of the primer, a conventional test pattern may be printed, at **429**, upon the medium to enable the user to assess the quality of print following the intermittent printhead clearing process. The printer then proceeds with its normal printing chores, at **431**.

The foregoing process can also be considered as a function of time. A band of printhead ink output using a conventional spitting nozzle clearing process is illustrated in FIG. **5**. In a print cartridge which contains three colors of ink, the process of spitting ink droplets occurs for each of three individual groups of nozzles in the printhead. This process can be represented by three bands of color which would be printed upon a medium if the printhead were scanned across the medium at a constant velocity. In practice, the printhead is parked at the service station **117** and the expelled ink droplets are deposited in the spittoon. Shown in FIG. **5** is a graphic representation of three bands of color (cyan, magenta, and yellow) which has an abscissa dimension of the number of expulsions from the nozzles. Conventional printers are known to use 2000 expulsions (of each color) from each nozzle at a continuous rate of droplet expulsion ranging from approximately 3000 to 6000 droplets per second.

Using the present invention, a similar band of printhead ink output is illustrated in FIG. **6**. Again, the abscissa is dimensioned in the number of expulsions (which are related to a time value). It is an important feature of the present invention that the ink droplets are intermittently or discontinuously spit from individual nozzles at particular times to clear the nozzles and associated ink feed and firing chambers. In the preferred embodiment of a multicolor prim cartridge, 300 expulsions of a color are continuously spit at an expulsion rate of 1500 droplets per second over a time segment $t_1=0.2$ second, illustrated as the cyan color burst **601**. For a period of time ($t_2=0.1$ second) the printhead pauses from droplet expulsion. A stairstep ink expulsion **603** over a time segment of $t_3=0.11$ second from the cyan color nozzle group follows the pause time t_2 during which two nozzles from alternate columns of nozzles from opposite ends of the printhead are fired at a rate of 1500 droplets per second in the sequence described in relation to the flowchart of FIG. **4**. This process causes each nozzle to spit twenty times in succession and forces a time delay between the expulsion of ink from adjacent nozzles. Following the stairstep expulsion **603**, a second pause time t_4 (which in the preferred embodiment is 0.1 second) is observed before a second burst, **605**, of 300 expulsions of cyan color at an expulsion rate of 1500 droplets per second for a time segment of $t_5=0.11$ second is performed. A third pause time ($t_6=0.1$ seconds) and a third stairstep expulsion **607**, like stairstep expulsion **603**, follows the second burst **605** for a time segment of $t_7=0.11$ second.

The foregoing process is then repeated for the magenta colored ink, commencing with a 300 expulsion burst at **609** and then repeated for the yellow colored ink, commencing at **611**. An alternative embodiment of the present invention causes the corresponding nozzles of each color to eject ink simultaneously with its corresponding nozzle of each other color of ink. Not shown is a repeating of the entire process starting with the cyan burst. Such a repeat may be performed as needed.

An alternative embodiment of the discontinuous spitting to clear blocked nozzles is illustrated in FIG. **7**. The continuous droplet bursts described with relation to FIG. **6** (bursts **601**, **605**, **609**, and **611**) are performed in the same sequence as described previously. The pause time between bursts likewise are similar to the previously described times. The two stairstep expulsions, **701** and **703**, for cyan ink; **705** and **707**, for magenta ink; and **709** and **711**, for yellow ink are expelled in a different pattern than described previously. Alternate column nozzles at opposite ends of the printhead are fired two at a time in sequence, as they were in the stairstep expulsion **603**, but each nozzle droplet firing event occurs twice during the stairstep expulsion time segment t_3' for a total of 40 spits (20 spits per event) for each nozzle. In the preferred embodiment, $t_3'=t_7=0.21$ second. After each nozzle (of the particular ink color) has fired once, the firing order is reversed. Nozzle firing resumes from the two centered but alternate column nozzles and continues for each nozzle to be fired again for one more pulse of ink to be expelled, ending with the alternate nozzles at opposite ends of the printhead. This process is repeated for magenta colored ink (stairstep expulsions **705** and **707**) and for yellow colored ink (stairstep expulsions **709** and **711**). If necessary, the entire pattern of spitting can be repeated, as necessary, starting with the burst of cyan ink. Although a particular stairstep expulsion pattern is employed in the alternative embodiment, a different or random stairstep expulsion pattern will effectively improve the nozzle clearing process as long as the duty cycle of any particular nozzle during the stairstep expulsion pattern is less than 15 percent of the burst duty cycle of a nozzle.

If the print cartridge is only a single color cartridge (for example, black ink) a single or a few repetitive patterns of discontinuous nozzle and ink channel clearing may be performed as described previously. Regardless of the ink color, it is believed that the nonvolatile ink residuals which form around the nozzle opening are cleared by both the mechanical force of the ink droplet expulsion and the dissolving of the residuals by the circulation of fresh ink in the firing chamber. The time dwell in heating using a discontinuous expulsion process allows the heating of the ink and surrounding printhead assembly to extend further into the structure of the printhead and down the ink feed channel from the heater resistor. Such a greater heat spreading further improves the viscosity of the ink and improves the ability of the warmed fluid ink to dissolve dried ink residuals in the ink feed channels. When a continuous firing process is used, however, the ink in the firing chamber is boiled and expelled, thereby carrying a significant portion of the heat energy away with the expelled ink droplet. This results in less heat spreading within the printhead structure and less removal of ink residuals.

We claim:

1. A method of clearing blocked nozzles in an inkjet printer printhead having a mechanism for expelling ink from nozzles, the method comprising, without interruption or manual intervention, the steps of:

(a) expelling ink in a first time segment from the printhead nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions;

(b) pausing from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segment; and

(c) expelling ink in a second time segment from the printhead nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pausing step, each printhead nozzle expelling ink at least once during said second time segment, such expelling of ink in a second time segment further comprising the step of sequentially expelling ink from each printhead nozzle of predetermined nozzles of the printhead nozzles as said second pattern of nozzle expulsions at a duty cycle of no more than 15 percent of that of said expulsion of ink in a first time segment for a first number of nozzle expulsions.

2. A method in accordance with the method of claim **1** wherein said step of (a) expelling ink in said first time segment further comprises the step of simultaneously expelling ink from each printhead nozzle in repetitive bursts for the full duration of said first time segment as said first pattern of nozzle expulsions.

3. A method in accordance with the method of claim **1** further comprising the step of placing the printhead in a position whereby ink which is expelled from the nozzles is captured without reaching the medium upon which printing is to occur.

4. A method in accordance with the method of claim **1** further comprising the step of entering a print status mode after said ink is expelled in said second time segment.

5. A method in accordance with the method of claim **1** wherein step (c) further comprises the step of expelling ink from at least two predetermined groups of printhead nozzles in said second pattern.

6. A method in accordance with the method of claim **5** wherein said step of expelling ink from at least two predetermined groups of printhead nozzles further comprises the step of sequentially expelling ink from corresponding nozzles of each of said at least two predetermined groups of printhead nozzles.

7. A method in accordance with the method of claim **1** further comprising the step of repeating steps (a) to (c).

8. A method in accordance with the method of claim **1** further comprising the step of printing a test pattern on the medium following step (c).

9. An inkjet printer which expels ink droplets onto a medium from an ink reservoir and which intermittently clears plugged nozzles, comprising:

a printhead which has a plurality of nozzles disposed in an orifice plate:

a plurality of ink ejection chambers fluidically coupled to the ink reservoir and each said ink ejection chamber coupled to a respective one nozzle of said plurality of nozzles;

a plurality of ink ejectors, at least one of said ink ejectors disposed in each of said plurality of ink ejection chambers;

a microprocessor, coupled to said plurality of ink ejectors, which commands said plurality of ink ejectors in sequence to expel ink in a first time segment from said plurality of nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions, said first pattern of nozzle expulsions further including a simultaneous expulsion from each printhead nozzle in repetitive bursts for the duration of said first time segment at a duty cycle of no more than 15 percent of that of said expulsion of ink in a second time segment for a second number of nozzle expulsions;

pause from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segment; and

expel ink in a second time segment from said plurality of nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pause, each printhead nozzle expelling ink at least once during said second time segment.

10. An inkjet printer having a printhead with a mechanism for expelling ink from nozzles and an apparatus for clearing blocked nozzles, the printer comprising:

means for expelling ink in a first time segment from the printhead nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions including means for sequentially expelling ink from predetermined nozzles of the printhead nozzles as said first pattern of nozzle expulsions at a duty cycle of no more than 15 percent of that of said expulsion of ink in a second time segment for a second number of nozzle expulsions;

means for pausing from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segments; and

means for expelling ink in a second time segment from the printhead nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pause each printhead nozzle expelling ink at least once during said second time segment.

11. An inkjet printer in accordance with claim **10** further comprising means for expelling ink from at least two predetermined groups of printhead nozzles in said first pattern.

12. An inkjet printer in accordance with claim **11** wherein said means for expelling ink from at least two predetermined groups of printhead nozzles further comprises means for sequentially expelling ink from corresponding nozzles of each of said at least two predetermined groups of printhead nozzles.

13. A method of clearing blocked nozzles in an inkjet printer printhead having a mechanism for expelling ink from nozzles, the method comprising, without interruption or manual intervention, the steps of:

(a) expelling ink in a first time segment from the printhead nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions, said step of expelling ink in said first time segment including the step of sequentially expelling in from predetermined nozzles of the printhead nozzles as said first pattern of nozzle expulsions at a duty cycle of no more than 15 percent of that of said expulsion of ink in a second time segment for a second number of nozzle expulsions;

(b) pausing from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segment; and

(c) expelling ink in a second time segment from the printhead nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pausing step, each printhead nozzle expelling ink at least once during said second time segment.

14. A method in accordance with the method of claim **13** wherein step (a) further comprises the step of expelling ink from at least two predetermined groups of printhead nozzles in said first pattern.

15. A method in accordance with the method of claim **14** wherein said step of expelling ink from at least two predetermined groups of printhead nozzles further comprises the

step of sequentially expelling ink from corresponding nozzles of each of said at least two predetermined groups of printhead nozzles.

16. An inkjet printer which expels ink droplets onto a medium from an ink reservoir and which intermittently clears plugged nozzles, comprising:

a printhead which has a plurality of nozzles disposed in an orifice plate;

a plurality of ink ejection chambers fluidically coupled to the ink reservoir and each said ink ejection chamber coupled to a respective one nozzle of said plurality of nozzles;

a plurality of ink ejectors, at least one of said ink ejectors disposed in each of said plurality of ink ejection chambers; and

a microprocessor, coupled to said plurality of ink ejectors, which commands said plurality of ink ejectors in sequence to:

expel ink in a first time segment from said plurality of nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions,

pause from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segment; and

expel ink in a second time segment from said plurality of nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pause, each printhead nozzle expelling ink at least once during said second time segment, said expulsion of ink in a second time segment including the sequential expulsion of ink from predetermined nozzles of the printhead nozzles as said second pattern of nozzle expulsions at a duty cycle of no more than 15 percent of that of said expulsion of ink in a first time segment for a first number of nozzle expulsions.

17. An inkjet printer in accordance with claim 16 wherein said second pattern of nozzle expulsions further comprises a sequential expulsion from predetermined nozzles.

18. An inkjet printer in accordance with claim 16 further comprising a service station whereby ink which is expelled from the nozzles is captured without reaching the medium upon which priming is to occur.

19. An inkjet printer having a printhead with a mechanism for expelling ink from nozzles and an apparatus for clearing blocked nozzles, the printer comprising:

means for expelling ink in a first time segment from the printhead nozzles in a first pattern of nozzle expulsions for a first number of nozzle expulsions;

means for pausing from ink expulsion for a period of time immediately following said first time segment, said period of time being equal to or less than said first time segment; and

means for expelling ink in a second time segment from the printhead nozzles in a second pattern of nozzle expulsions for a second number of nozzle expulsions immediately following said pause each printhead nozzle expelling ink at least once during said second time segment, said means for expelling ink in said second time segment further comprising means for sequentially expelling ink from predetermined nozzles of the printhead nozzle as said second pattern of nozzle expulsions at a duty cycle of no more than 15 percent of that of said expulsion of ink in a first time segment for said first number of nozzle expulsions.

20. An inkjet printer in accordance with claim 19 wherein said means for expelling ink in said second time segment further comprises means for simultaneously expelling ink from each printhead nozzle as said second pattern of nozzle expulsions.

21. An inkjet printer in accordance with claim 19 wherein said means for expelling ink in said first time segment further comprises means for simultaneously expelling ink from each printhead nozzle in repetitive bursts for the duration of said first time segment as said first pattern of nozzle expulsions.

22. An inkjet printer in accordance with claim 9 further comprises means for placing the printhead in a position whereby ink which is expelled from the nozzles is captured without reaching the medium upon which printing is to occur.

23. An inkjet printer in accordance with claim 19 further comprises means for expelling ink from at least two predetermined groups of printhead nozzles in said second pattern.

24. An inkjet printer in accordance with claim 23 wherein said means for expelling ink from at least two predetermined groups of printhead nozzles further comprises means for sequentially expelling ink from corresponding nozzles of each of said at least two predetermined groups of printhead nozzles.

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